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AN ACCOUNT OF THE STEAM ENGINE.

For the purposes of this article, I have consulted the following essays.

1st. The articles steam, and steam engine, in the old Edinburgh Encyclopedia, republished in this country by Dobson. I believe these articles were drawn up by Professor Robison, of Edinburgh, and are well executed. As this work is common in America, I have not chosen to copy these articles, but I earnestly recommend them to the careful (not the perusal, but) study of the reader who wishes to become acquainted with this subject. In studying these articles, care must be taken to refer to the additions made in the supplement to that Encyclopedia, under the head of „ Steam engine."

2dly. An account of steam engines, by Olinthus Gregory, the compiler of Gregory's Encyclopedia, a work for the most part too brief and superficial to communicate valuable knowledge: but the mechanical articles are tolerably well executed, it being a subject to which he had much attended. The account of steam engines is extracted from his treatise on mechanics, theoretical, practical and descriptive. Second edition, 1807. The arti-

cle is chiefly drawn up by Mr. J. C. Hornblower, who had a law suit with Mr. James Watt, of Birmingham, wherein the latter was plaintiff, on the subject of infringing the patent right of Mr. Watt. Mr. Hornblower was cast. The article in Gregory, is drawn up with so much illiberality of remark on the pretensions of Mr. James Watt, and on the article in the Edinburgh Encyclopedia above referred to, that I have been able to make a few extracts only from it, for the use of the Emporium. This tract of Gregory's induced

3dly. A review of Gregory's account steam engines, in the 26th number of the Edinburgh Review, for January 1809. This very able and very severe article, I have been given to understand, was written by Professor Playfair, of Edinburgh, whose very brief but very neat account of the history of steam engines, I shall extract.

4thly. I have consulted, and shall use, Nicholson's account of Watt's steam engine in his 8vo. Encyclopedia; a work, written under the pressure of straitened circumstances, and therefore not with the usual care of this most useful and industrious man.

5thly. I have consulted the following articles on the subject in Nicholson's Journal, viz. 1 V. 419. 2 V. 46 228. 364. 476. 3 V. 86. 161. 4 V. 545. 5 V. 147. of the quarto edition. Of the 8vo. series, 1 V. 161. 2 V. 68. 6 V. 218. 249. 7 V. 310. 8 V. 169. 262. 11 V. 93. 243. 12 V. 1. 174. 294. 316. 17 V. 5. 18 V. 260. And the following articles in that collection on horse power, 9 V. 214. 11 V. 96. 98. 145. 264. 271.

I have also consulted the articles giving an account of Cartwright's, Trevethic's, and Woolfe's improvements on Watt's engine in Tilloch's Philosophical Magazine, wherein the articles relating to the steam engines, are to be found in 1 V. 1. 16 V. 372. 17 V. 40. 164. 19

V. 133. 275. 21 V. 254. 23 V. 123. 335. 26 V. 316.

As there is no general index to these works, I apprehend it will be useful to note the places where information on this subject can be found in them.

The common histories of the steam engine, include a description of Savary's, Newcomen's and Cawley's, and Watt's. I shall add, some account of the improvements of Hornblower, Cartwright, and Woolfe. Also, Oliver Evans's account of his steam engine. I do not know that I can get all the plates ready for the present number, but I shall insert herein the methods of consuming smoke, because those plates are likely to be completed in time.

On the means of CONSUMING THE SMOKE, *arising from large furnaces, particularly from steam engines.*

I would premise, that smoke, is a mixture of aqueous vapour—charcoal—and carburetted hydrogen, distilled off by means of heat from fuel.

When a candle or a lamp burns in the common method, they smoke. That is, the fuel instead of being burnt or consumed, is in part distilled away by the heat: for as there can be no combustion but by means of the oxygen of the atmospheric air, and as the outside only of the wick is in contact with the air, the fuel with which the outside is impregnated, only can be burnt: the oil or tallow of the inside, is distilled away and forms the smoke. Part of this is caught and inflamed as it escapes into the air; hence the flame of a candle extends beyond the point of the wick; but the whole of it is not burnt. What is not burnt is smoke.

To remedy this M. D'Argand, the inventor of the patent lamp, has contrived (by making the wick *thin*, and *circular*, and by admitting a current of air to both sides of the wick) to consume the whole of the fuel by supplying every part of it with atmospheric air in a strong cur-

rent occasioned by the rarefaction produced in the glass chimney. That this is a true account of the process, any one may satisfy himself, by closing the apertures of the grating at the bottom of the lamp, through which the air ascends up the chimney; and the wick no longer supplied with the oxygen of the atmosphere, will send off the combustible oil, unburnt in the form of smoke like a common lamp.

If a piece of wood be distilled, it furnishes an acidulous watery liquor, a large quantity of carburetted hydrogen gas, that is charcoal dissolved in hydrogen gas, and its own bulk of charcoal. Both the hydrogen gas and the charcoal, are combustible *with* access of air, but incombustible without it. The flame of a wood fire, is owing to the ascension of the carburetted hydrogen distilled off from the wood. The smoke is partly acidulous vapour, and partly unconsumed carburetted hydrogen.

Whatever is capable of being burnt gives out heat: for the oxygen of the atmosphere, when it combines with a combustible body, parts with the heat to which it is chemically united. That heat, becomes sensible, and acts upon the bodies around. The smoke attaches itself to the bodies it meets with, and sticks to them, and a quantity of carbon or charcoal is deposited: this mixture is called Soot.

When a quantity of coal is set on fire the same process takes place; a tar-acid vapour flies off mixed with carburetted hydrogen holding much carbon or charcoal in solution; this is the smoke, which when condensed in the chimney or on the bottom of a boiler, forms also soot; thicker, and containing more carbon, and volatile oil than the soot of wood.

Four ounces avoirdupois of pine saw dust, yielded me 12 quarts of carburetted hydrogen. The same weight of bituminous Liverpool coal, yielded me 18 quarts. Some

coal would yield 24 quarts. Soot then consists chiefly of unburnt charcoal.

Take out of the fire, a piece of charcoal about an inch or half an inch long, well lighted at one end. You may hold it in your fingers, and even excite by blowing, the lighted end, without being burnt. *Charcoal therefore is a very bad conductor of heat.* Take a piece of iron or brass, a foot long, and holding it at one end, thrust the other into the fire. Long before it approaches a red heat, your fingers will be burnt. *Metals therefore are very good conductors of heat.* Hence, when we suffer soot to accumulate at the bottom of our boilers, we exchange a very good for a very bad conductor of heat; and we must employ more fuel, for the purpose of communicating the same heat to the water. Hence it is a point of economy to consume the smoke under the boiler of a steam engine.

The method of consuming the smoke of furnaces, depends upon two principles: 1st. the vivid, well-lighted coals, are pushed forward, and the half lighted coals are not thrown upon or beyond them promiscuously, but placed at that part of the fire, where the body of vivid coals commences: hence the smoke arising from the half-lighted, can be made to pass over the lighted coals. But the smoke would rise up, if it were not, 2ly. that a current of air is admitted, and directed downward, so as to drive the rising smoke upon and over the surface of the red hot coals, where it is burnt and consumed as fuel.

Suppose the door frame of the fire place, shuts against a platform, not *level* with the fire as usually is the case, but raised above the burning fuel, &c. slanting downward from the inside of the door toward the fire; so that the coals can be easily pushed inward to any part of the fire; if then, there be a slit of an inch wide for instance, across the door, a current of air will pass through that slit over the fire in addition to the current of air that passes upwards

through the bars and among the fuel. By means of a piece of sheet iron placed slanting over the slit within-side, this current of air through the slit in the door, can be directed so as to drive the smoke of the fresh coals, down upon the burning coals, and there it will be consumed.

The three following methods, which can be well understood from the plates, have long been in use in England, and therefore can be employed for the purpose of consuming smoke as well here as there.

In the year 1791, the steam engines on Watt's construction at Manchester, consumed the smoke: the public complained that no method was adopted by the owners of other steam engines, and by the dyers in and near that town, to produce the same effect in their furnace-fires. I applied to Boulton and Watt, and obtained permission for any person to use their patent in this respect, whether connected with one of their engines or not. Of course the smoke of the furnaces was consumed generally, on paying a moderate premium for the use of the invention.

Several furnaces however were erected from time to time, and steam engines already put up previous to the improvements of Boulton and Watt, were worked with furnaces, which were not built on a construction necessary to consume the smoke. In the Monthly Magazine for 1796, the reader will find an account of six owners of steam engines and furnaces at Manchester, who were indicted at the quarter sessions for a nuisance, inasmuch as they did not use means to consume the smoke of their furnaces: they were convicted, and fined *one hundred pounds sterling each;* and the conviction was acquiesced in. I have no hesitation in saying that the neglect of employing such means, is just as much a nuisance in this country as in that. I now publish in a manner not to be mistaken, the methods of producing this effect; one or

other of which is in common use in Great-Britain, and either of which will answer the purpose. A steam engine of the power of a dozen horses, need not, and ought not, to send forth so much smoke as a common sitting room fire: the method of producing this effect, is not a tax upon the owner, but an advantage; for he consumes his fuel more perfectly, and none goes to waste. If steam engines continue to be erected in large towns, without having this improvement attached to them, instead of being as they might be, blessings to the neighbourhood, they will make our towns uninhabitable; and I would earnestly recommend that the legal question of *nuisance* should be settled, by an indictment brought against the offenders.

Specification of the Patent granted to Mr. JAMES WATT, *of Birmingham, in the County of Warwick, Engineer; for certain newly-improved Methods of constructing Furnaces or Fire-places, for heating, boiling, or evaporating of water, and other Liquids; which are applicable to steam-engines and other purposes; and also for heating, melting, and smelting, of Metals, and their Ores; whereby greater effects are produced from the Fuel, and the smoke is in a great measure prevented, or consumed.*

Dated, June 14, 1785.

TO all to whom these presents shall come, &c. Now KNOW YE, that, in compliance with the said proviso, and in pursuance of the said statute, I the said James Watt, do hereby declare, that the following is a particular description of the nature of my said invention, and in what manner the same is to be performed; that is to say, my said newly-improved methods of constructing furnaces or fire-places consist in causing the smoke or flame of the

fresh fuel, in its way to the flues or chimney, to pass, together with a current of fresh air, through, over, or among, fuel which has already ceased to smoke, or which is converted into cokes, charcoal, or cinders, and which is intensely hot; by which means the smoke and grosser parts of the flame, by coming into close contact with, or by being brought near unto, the said intensely hot fuel, and by being mixed with the current of fresh or unburnt air, are consumed, or converted into heat, or into pure flame free from smoke. I put this in practice, first, by stopping up every avenue or passage to the chimney or flues, except such as are left in the interstices of the fuel, by placing the fresh fuel above, or nearer to, the external air than that which is already converted into cokes or charcoal; and by constructing the fire-places in such manner that the flame, and the air which animates the fire, must pass downwards, or laterally, or horizontally, through the burning fuel, and pass from the lower part, or internal end or side, of the fire-place, to the flues or chimney. In some cases, after the flame has past through the burning fuel, I cause it to pass through a very hot funnel, flue, or oven, before it comes to the bottom of the boiler, or to the part of the furnace where it is proposed to melt metal, or perform other office, by which means the smoke is still more effectually consumed. In other cases, I cause the flame to pass immediately from the fire-place into the space under a boiler, or into the bed of a melting or other furnace. The drawing Figure 1 (Plate I.) shews a section of a fire-engine boiler, and its furnace or fire-place, which I have chosen for an example of the application of this new method to the heating and evaporating of water. A A is the boiler, which may be made of any form suitable to its use. B B is a flue, surrounding the boiler as usual. C is the uptake, or passage from the space under the boiler to the flues. D D is a funnel or flue for the flame to

Fig. 2.

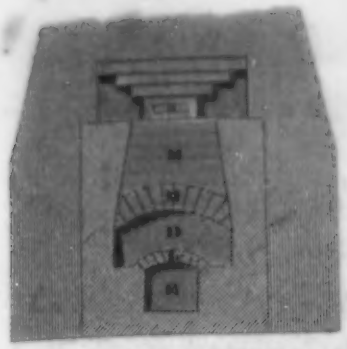


Fig. 3.

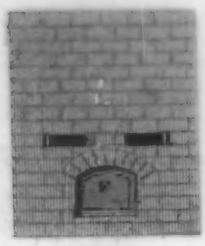


Fig. 4.

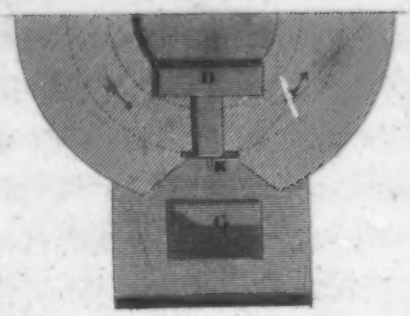


Fig. 5.

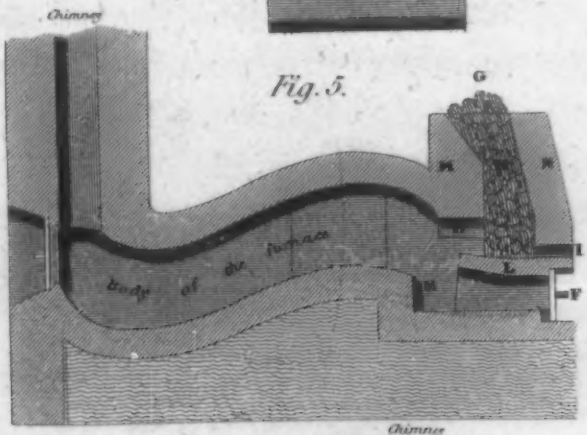


Fig. 1.

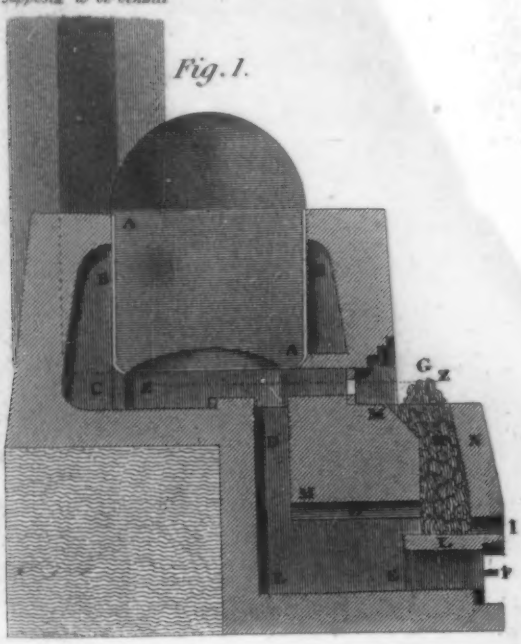
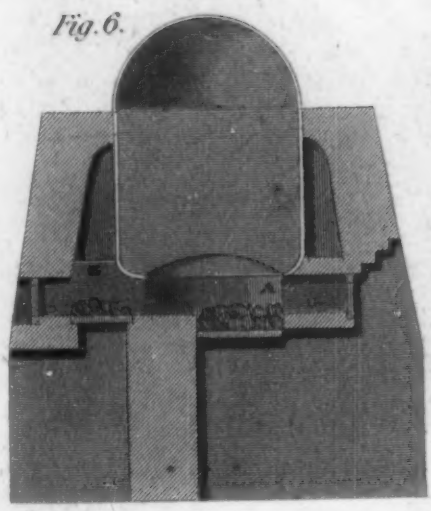


Fig. 6.



Scale for all the Figures

1 2 3 4 5 6 7 8 9 10

Tiebout. Sc.

come from the fire-place to the boiler. E E is a place to contain the ashes; and F is a door to take them out at, which must be kept continually shut during the time of working. G H is the fire-place: the fresh fuel is put in at G, and gradually comes down as the fuel below consumes. The part at H is very hot, being filled with the cokes or coals which have ceased to smoke. I is an opening or openings, to admit fresh air, and regulate the fire. K is a door into the space under the boiler; which, being opened, admits air, and stops the draught of the chimney when the operation is wanted to cease. Figure the second is a section of the same fire-place in the other direction; in which M M is the back of the fire-place; L the brick arch on which the fuel lies; and E the ash-hole. Figure 3 is an outside view of the same fire-place, shewing the air-holes I I, and the ash-hole door F; and Figure 4 is a plan of the same, with part of the boiler seating, taken in the line Z Z of Figure 1. The dotted lines represent the flues, and the darts point out the direction of the flame. The fire is first kindled upon the brick arch L, (Fig 1.) and when well lighted, more fuel is gradually added until it is filled up to G; and care is taken to leave proper interstices for the air to pass, either among the fuel, or between the fuel and the front wall N; and as much air is admitted at I I as can be done without causing the smoke to ascend perpendicularly from G, which it will do if too much air is admitted at I I. The dimensions of this fire-place are shewn by the scale, and are properly adjusted for burning about eighty-four pounds weight of coals in an hour; where greater or less quantities are required to be burnt, the furnaces must be enlarged or diminished accordingly; or, if much greater, more furnaces than one must be employed. Figure the fifth represents this new fire-place as applied to a furnace for melting iron and other metals, and construct-

ed without the funnel or perpendicular flue D in Figure 1. N. B. The same letters refer to the same parts in all the preceding figures. I also construct these new fire-places so that the part G H lies sloping, or horizontal, and otherwise vary the figure or form, and proportions, of the same; but, in all cases, the principle is the same; the fresh or raw fuel being placed next the external air, and so that the smoke or flame passes over, or through, the coked or charred part of the fuel. I also occasionally cover the opening G, and cause the air to enter only, or principally, at I I. Secondly, in some cases, I place the fresh fuel on a grate as usual, as at A A, (Figure 6,) and beyond that grate, at or near the place where the flame passes into the flues or chimneys, I place another smaller grate B, on which I maintain a fire of charcoal, cokes, or coals which have been previously burnt until they have ceased to smoke; which, by giving intense heat, and admitting some fresh air, consumes the smoke of the first fire. Lastly, be it remembered, that my said new invention consists only in the method of consuming the smoke, and increasing the heat, by causing the smoke and flame of the fresh fuel to pass through very hot funnels or pipes, or among, through, or near, fuel which is intensely hot, and which has ceased to smoke; and by mixing it with fresh air when in these circumstances; and in the form and nature of the fire-places herein mentioned, described, and delineated: the boilers, and other parts of the furnaces, being such as are in common use. And be it also remembered, that these new-invented fire-places are applicable to furnaces for almost every use or purpose. In witness whereof, &c.

Mr W.m Thomson's method of consuming smoke 1796.

Fig. 1.

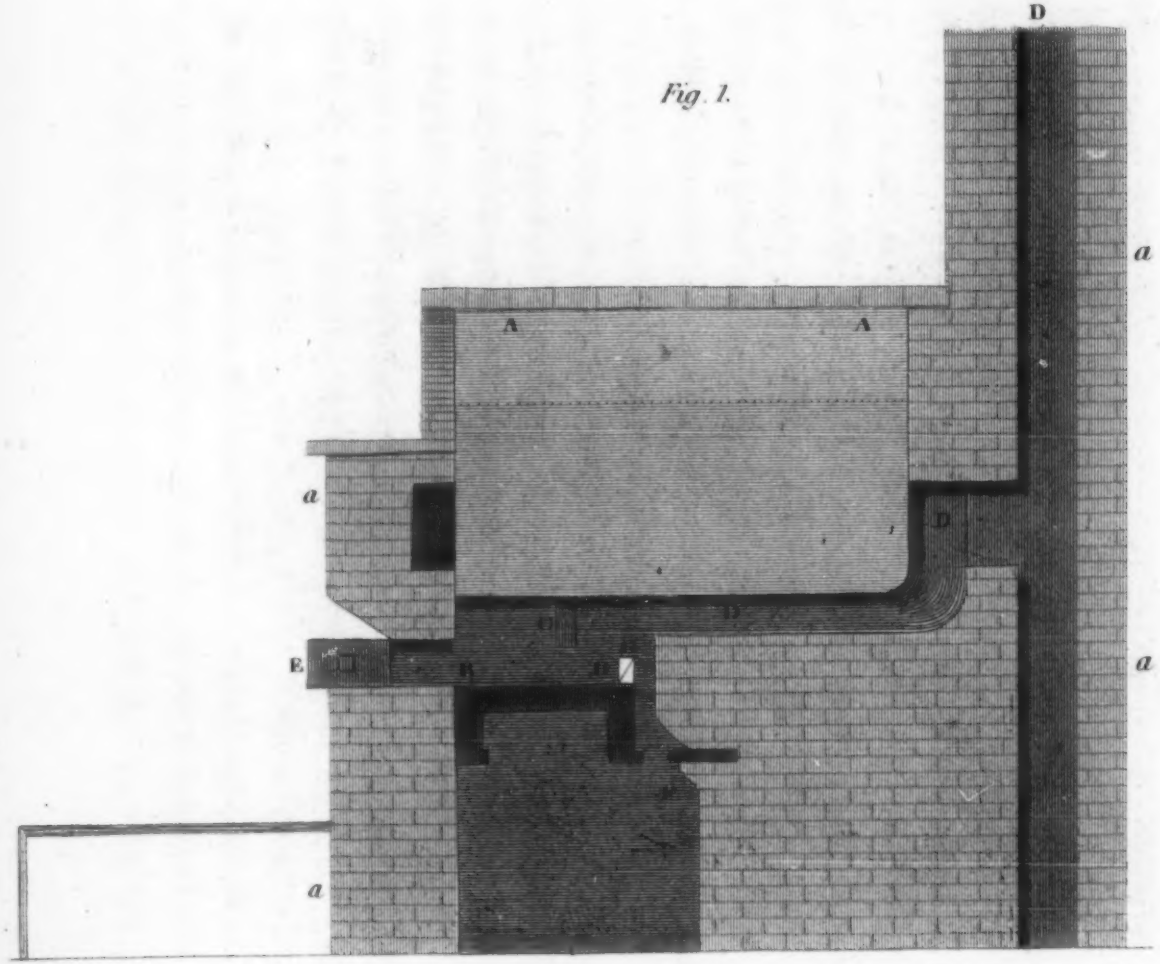
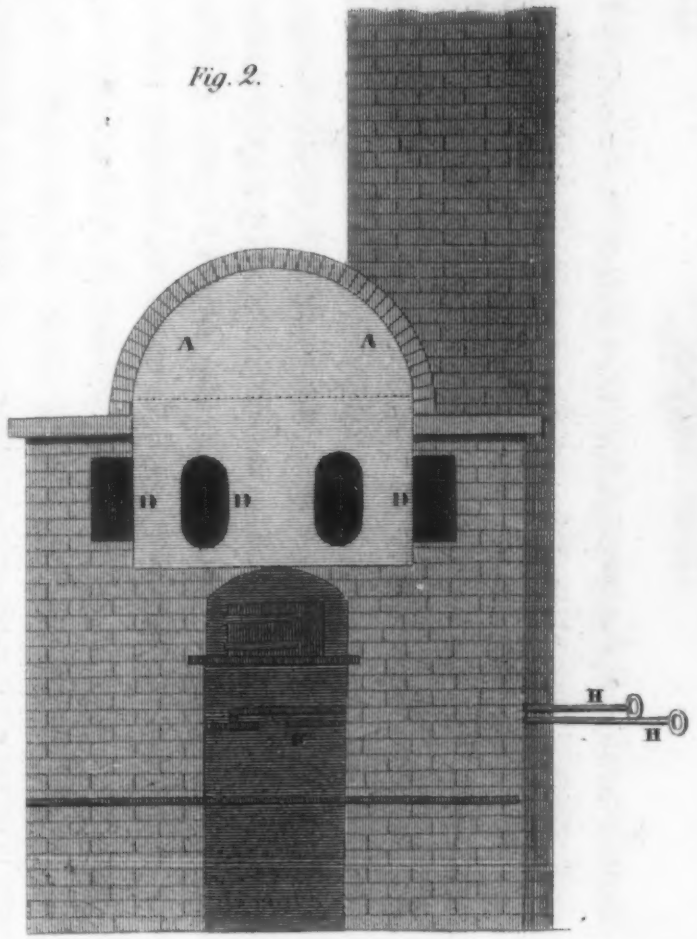


Fig. 2.



Tirbout sc.

Description of a Furnace for Steam-Engines, &c. which effectually consumes the smoke arising from it. In a letter to the editors, from Mr. WILLIAM THOMSON, *of Bow-Lane.* 4 *Rep. Arts,* 1796.

WITH A PLATE.

AS steam-engines are much made use of in this kingdom, and, at the same time, are often found very disagreeable on account of their smoke; I herewith send you a description, and drawing, of a furnace which will effectually consume the smoke arising from it, without requiring more coals than usual, as has been the case with former contrivances for that purpose. It may be adapted to any boiler or copper already set up, and at a very small expence.

Fig. 1, is a section of an oblong boiler, and fire-place.

a a a a. The brick work in which boilers are usually set.

A A. The boiler. Two iron flues run through this boiler, and also go round it.

B B. The fire-place; which must be about one third longer than they are generally made.

C. An arch, which runs across the fire-place, two inches lower than the bottom of the flue under the boiler, and about the middle of the fire-place.

D D D D. Flues through which the hot air ascends, and spends its heat on the boiler.

E. The door of the fire-place; which must have a small shutter in it. Through this shutter the coals must be gently stirred up, by the slice or poker, taking care not to injure the arch, nor to raise too great a quantity of coals at once.

F is a small space left behind the fire, for a current of air to come through, as in the patent lamps.

G. A brick placed with its whole length across the fire-place, to hinder the coals from falling down the space F, and choking it.

Fig. 2, is a front view of the same boiler, and fire-place; in which the same letters represent the same parts.

HH are two slides, the one shifting backwards the other forwards, to make the space F, for the current of air, larger or smaller, as, by practice, may be found best.

Manner in which this Furnace operates.

The arch C hinders the smoke from going up the chimney, and obliges it to pass through the fire behind it; which has a very strong draught, and burns the smoke as it passes through it. The air which comes up through the space F gives fresh vigour to the flame, which consumes any smoke that may be left.

It must be observed that too much air will have a very bad effect, as it will cool the flame: therefore the slides H H must be regulated in such manner as the operator may find most advantageous.

The shutter in the door E must also be of a proper size; as its being too large or too small will be prejudicial.

I am, &c.

W. THOMSON.

Method of consuming smoke by James and John Robertson, of Tradestown, near Glasgow, Engineers. Patented August 13, 1800. *Rep. Arts. A. S. No.* 96.

Specification and description of the nature of a new and improved method of constructing furnaces, for the application of fire to steam-engines and boilers of various descriptions, and also the application of fire to many other purposes and branches of manufacture where heat is applied by means of a furnace, by which invention and im-

provement, a very considerable saving of fuel is effected from the immediate conversion of the whole, or very nearly the whole of the smoke arising from the fuel into flame: first, the said invention in principle consists in supplying the burning fuel more fully with air, having this fuel more in a body together, and a less quantity in combustion, at the same time, than what usually takes place in other furnaces, which are applied to the same uses; in applying the fuel with a portion of fresh air, admitted from an opening made for that purpose, and directed in such a manner as it may come in contact with the smoke from the kindling coal and great heat of the furnace together, and the fuel being more fully supplied with air, and consequently a greater degree of heat taking place, and the smoke and fresh air uniting in the great heat, the smoke is inflamed, and rendered useful in adding to the heat of the furnace; besides, this portion of fresh air is so conducted as to act partly on the kindling or kindled fuel, and raising it to a greater degree of heat, after it has served its purpose by uniting with and inflaming the smoke; and therefore is employed, in some measure, usefully, even after the coal has ceased to smoke: secondly, to the above may be added, the form of the furnace, which is so constructed, that the full kindled fuel is kept backward in the furnace, while the fresh coal lies before, and is more gradually kindled than if introduced further among the full kindled fuel, while the heat of the furnace is little injured or damped by the introduction of fresh coal, as is more fully described in the practical description of the furnace. The coal is admitted into the furnace by a hopper, feeder, or mouth-piece, A (Fig. 7 and 8), made of cast iron (but which may be made of other materials), and inclined to the horizon, as in Fig. 7; so that the coal in it, may in some measure, fall into the fire-place, above the bars, as the fuel is spent; in the upper part of this hopper, feeder, or mouth-piece, is a Plate,

a (Fig. 7 and 8), placed at a small distance, or from about three-eighths to three-fourths of an inch from the upper side of the hopper, betwixt which plate, and upper plate, or side of the hopper, a stream of air rushes downward on the fire, at about half a right-angle to the horizon, which stream of air assists in consuming the smoke, as formerly mentioned, and more fully described hereafter. B, Fig. 7, is a section of the bars, which are, in general, a little inclined to the horizon, as in the figure that the fuel may more easily fall, or be pushed backwards, in the furnace; at *c*, is an opening above the bars, and below the lower end of the hopper, which is in general fitted with a grated door or doors, which open for the more convenient cleansing of the furnace, and the grated form of the doors is also designed for admitting air into the fuel, as well as at the bars, consequently the air is more concentrated in the middle of the burning fuel, and produces a greater heat than if admitted only betwixt the bars; this grated form of the doors is also convenient for the admission of a poker or instrument for pushing backward the kindled fuel, while the fresh coal, or that which is not so well kindled, falls down to supply its place; in some others of these furnaces, the opening below the lower end of the hopper, and above the fore end of the bars, is left without doors at all; at this opening, it is convenient, when the fire is mended, to push the coal from the fore side backward, as mentioned above, or it may be pushed backward with a hooked poker, P, by applying the hooked part of it through the furnace bars below; by either of which means the kindled coals are put backwards, while the fresh coal, or that which is not so well kindled, falls down to supply their place; that is, the coals, in the situation *c*, are pushed towards *d*, while those in the situation *f* fall down to supply the place of those which were driven from *c* towards *d*; by such means, the strength or heat of the fire is not much

damped by the introduction of fresh coal, and the coals which have fallen from *f* towards *c*, are not so rapidly kindled as if introduced above the burning fuel: same time the smoke which arises from these newly-introduced coals, passes partly through the full-kindled coal and partly over, and in contact with the great heat of the burning fuel, and, meeting at the same time with the current of fresh air coming downwards, and tending also to drive the smoke still nearer to the bright kindled fuel, does in general completely inflame the smoke, and render it useful in adding to the heat of the furnace. Another end obtained by the stream of fresh air, is to keep in some measure the great heat of the furnace from acting so violently on that part of the hopper which is nearest it, and mostly exposed to its heat, and liable to be damaged thereby, which it does by the continual current of fresh cool air that is in contact with those parts; the construction of the furnace may be much varied; but the chief improvements are, that the fuel in combustion is supplied with air by the foreside as well as by the bars, the hopper is placed in such a situation that the kindled or unkindled coal may in part fall to the foreside of the furnace above the bars, as the other fuel is pushed backward in the furnace, and the admission of fresh air to pass over the burning fuel by means of a definite space or spaces, opening or openings, made for that purpose; so that this stream, current, or currents of air, partly come in contact with the burning fuel itself, forcing also the smoke with more immediate union with the burning fuel and great heat of the furnace. The Patentees do not pretend any claim to the admission of fresh air as a new principle, as they are sensible that this has been known long ago, and practised by admitting it at the furnace door, shutter, or mouth-piece, and at the opening where the coals are admitted into the furnace; their claim rests upon what has been

formerly stated, together with the form of the furnace, and its variations after-mentioned; the success of the furnace depends also upon a considerable degree on what is called the draught of the furnace; that is, the chimney and flues so constructed, as a sufficient current of air may pass through the fire to bring it to a proper degree of heat; also, that the current of fresh air may have such force as to come pretty much in contact with the burning fuel, and to convey the smoke along with it through the hottest of the flame; if this is not the case, the smoke will not be so completely consumed in these furnaces. The hopper is allowed to be kept as full of coal as possible, and either wholly or in part small coal, so as to prevent air as much as possible getting in by that passage; this must be attended to when the furnace is in its ordinary working state; yet, sometimes, it is necessary to keep this opening of the hopper, either wholly, or in part, open, when there is little heat wanted.

Description and reference to the draughts.

Fig. 7, is a side view, or section of the furnace, as if applied to a boiler, and cut through the middle. Fig. 8, is a front view of the furnace in perspective, the hopper having a division in the middle, and two regulating plates for the admission of fresh air. Figs. 7 and 8, A, the hopper into which the coals are put to supply the furnace, *a* the regulating plate; above which and below, the higher plate *b* of the hopper, a stream of fresh air is admitted to this plate; *a* is made to turn on a pin pivot or centre, so that it may be brought nearer to, or recede further from the uppermost at the point *n*, Fig. 7, for regulating the quantity of air admitted betwixt the plate as occasion requires; this plate is sometimes made fast, or kept so, after adopting a space which is judged sufficient for the quantity of fresh air but on other occasions, as in steam engines, it is

Method of consuming Smoke by I. & I. Roberton of Glasgow. 1800.

Fig. 8.

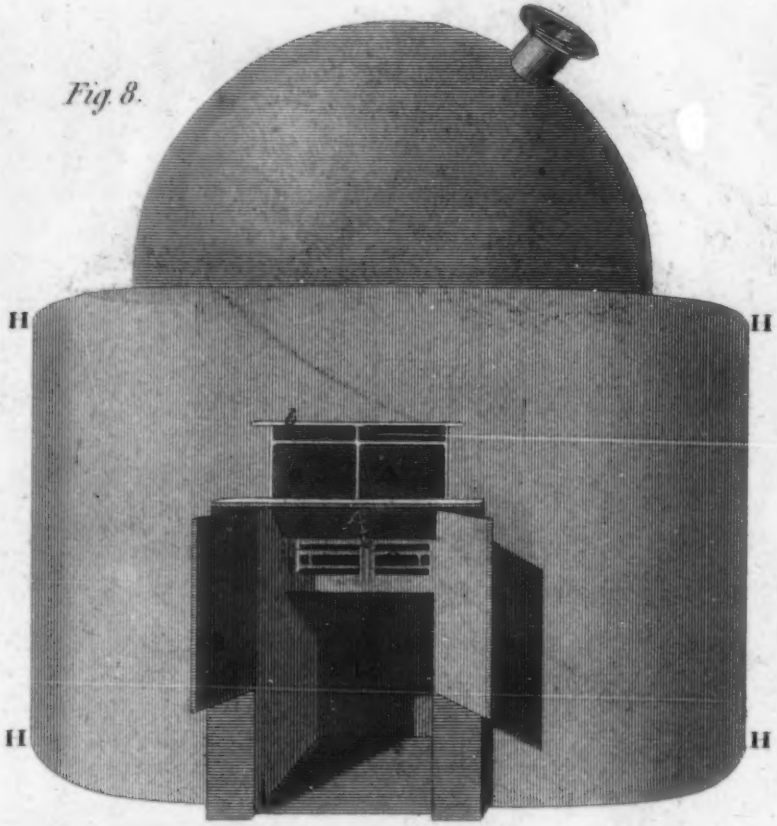


Fig. 7.

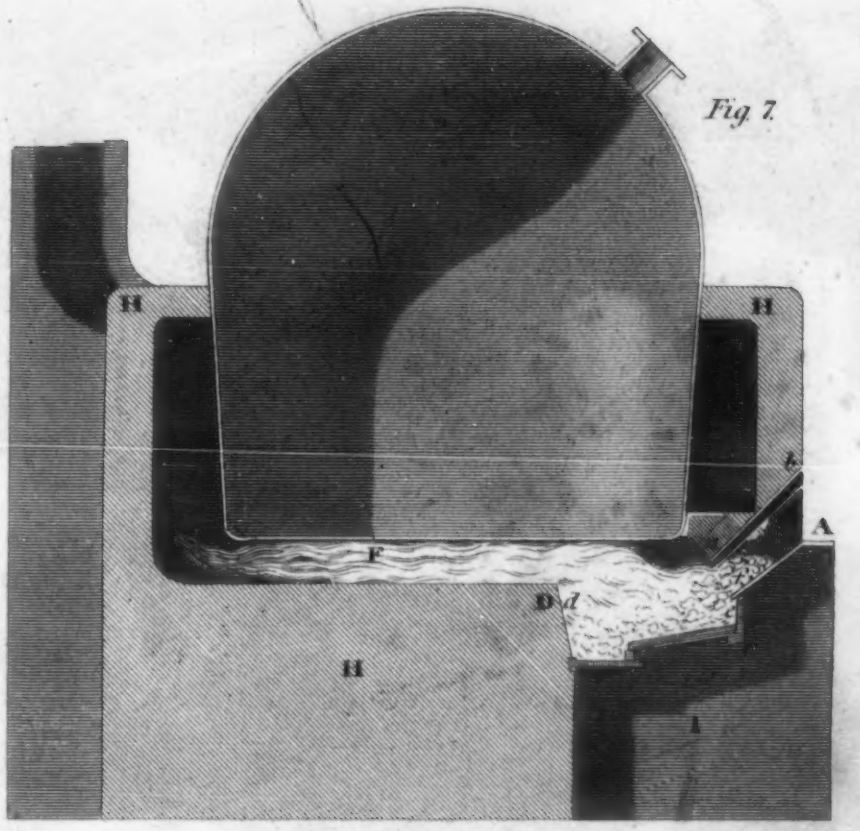


Fig. 10.

Fig. 9.

adviseable to give it less or more opening according to the state of the fire, that is, when coals are newly introduced into the fire-place, to give the greatest quantity of fresh air, and when they are pretty well kindled to give less air. F F F, Fig. 7, the flues beneath and round the boiler; that round the boiler, may be in any of the present well-constructed forms; that beneath the boiler, as in the drawing with a breast D, to prevent the coal getting so far backward in the furnace, and also to direct the flame on the bottom of the boiler: this breast is also necessary for the more complete combustion of the smoke, as by that means, the fresh air, smoke, and flame are more completely combined than if the breast were wanting, or ill-formed; at *r* is represented a shutter, which is sometimes used in steam engine boilers for the purpose of getting the refuse of the fuel taken from the furnace by opening the said shutter; in other cases, the breast of the furnace D coincides with *d* at the ends of the bars. G, Figs. 7 and 8, the grated-doors, or opening into the fire-place; I, the ash-pit below the furnace; L, Fig. 8, a catch, or bar, which slides along the bottom plate of the hopper, for keeping the grated-doors shut; H H H, &c. the brick-work for furnace and boiler. K, Fig. 7, a piece of cast-iron in a horizontal position, which joins the under plate of the hopper, for the more ease and convenience in putting in the coals, the hopper may be made in one or more pieces, as inclination or choice may direct, or of any materials which it may be thought prudent to adopt, but they are usually made with five plates of cast-iron; M representing one of the side plates, N the uppermost, O the undermost, and P the regulating-plate; the side plates having tenons which fit into mortices in the top and bottom plate, which may easily be conceived; on the side plates are detents or abutments, which serve as a centre for the regulating-plate to turn upon; on this plate are also two

abutments which rest on the other abutments of the side plates when this plate is put into its place; this plate by such means may be taken out, or put in at any time it is found necessary, without meddling with any other part of the hopper: another method is to have the bottom plate to come out, and in the same manner as the regulating plate; also, that it may fold up or down to any inclination; this form is very commodious for allowing access into the fire-place to get it repaired, or the like, or for having the fire quickly taken from it altogether, for by folding the plate to a level as represented by the dotted line, Fig. 9, the coal which is in the hopper is prevented from falling into the fire-place, and there is a greater space left to get into it; this form may either admit or not of the grated-doors; indeed the simple opening does very well. Fig. 9, is a representation of the side of the hopper, in this form: another method of the hopper, and letting in of air, is by making the underside of the top plate with cheeks, or grooves, as that the fresh air may rush down in them above the fuel that lies in the hopper, for when the hopper is fitted in as close with coal as it can be, these grooves or cheeks prevent the coal from getting into them, and form separate and definite spaces for the air to rush down on the burning fuel, and perform the same office as the regulating plate, though the proper quantity cannot be so well adjusted this way, yet the only way to accomplish this is to have these grooves or cheeks made as near the proper size as possible; they ought also to be so narrow, that little of the coal will get betwixt them. Fig. 10, is a front view of the hopper, in the state where A represents the opening coals are put into; another method is to let in the current of fresh air above the uppermost plate of the hopper, this may be done either by another plate placed above, or the building so formed over it, as that a proper quantity of fresh air may get in, and in a proper direction;

indeed, this may be accomplished many ways in a greater or lesser degree, by letting in a definite quantity, directed in such a manner as to come in contact with the fuel, though perhaps in no way better than the methods explained; to make this furnace more complete, doors are placed to the front, with a sufficient space below them to let air into the furnace, these doors are represented by S S, Fig. 8, as standing open; they are kept shut while the furnace is going, except when coals are put in, or the bars cleansed, or the like when they are opened for that purpose; the use of these doors is to prevent, in a great measure, the radient heat that comes from under the bars and from the opening at the foreside from escaping; this also adds something to the draught or well-going of the furnace, as this heat when suffered to escape rarifies the air before the furnace, which air passes upwards, performing in a small degree that which a chimney does, and depriving the fire of a portion of air which it otherwise has when the doors are shut; these furnaces are made of various sizes, according to the uses they are applied to; in some large ones there is a division in the middle of the hopper, as in Fig. 8; this size, as measured by the scale, will serve a steam-engine boiler of about nine or ten feet diameter; lesser furnaces do not need this division in the middle of the hopper. In witness whereof, &c.

Of Steam and the Steam Engine.

Before I enter directly upon the subject of the steam engine, it will be necessary that the reader should fully comprehend the doctrines of fluidity, evaporation, latent heat and specific heat; and also the facts ascertained respecting the expansive force of steam. The first of the following extracts, which with great brevity and great clearness gives a summary of the doctrine of heat or calo-

ric as connected with fluidity, and vapour or steam, I owe to the 6th edition of Dr. Henry's chemistry, which is not yet commonly known in this country. The second extract, I have taken from Gregory's treatise on mechanics, theoretical, practical, and descriptive, Vol. 2. The tables of Betancourt and Dalton, are from Prony's architecture hydraulique, and the 5th vol. of the Manchester transactions. The account I shall give of the history of the steam engine, I shall adopt from Gregory, Hornblower, and Playfair. Gregory's account in his Encyclopædia, and his plate to that account which I have adopted, are abridged and borrowed from the article steam engine in the Edinburgh Review, and Nicholson and Tilloch's Magazines. And I again request my readers to turn to the excellent articles, "steam," and "steam engine" in that Encyclopædia (Dobson's edit.) as indispensible to be carefully perused, by those who would acquire knowledge on the subject, notwithstanding the illiberal remarks of Gregory and Hornblower on that article and the compiler of it.

Caloric the Cause of Fluidity.

I. *The temperature of melting snow, or of thawing ice, is uniformly the same at all times, and in all places.*—This may be ascertained by the thermometer, which will always, when immersed in liquefying ice or snow, point to 32° of Fahrenheit, whatsoever may be the height of the barometer, or the elevation, above the sea, of the place where the experiment is made. (Shuckburgh, Philosophical Transactions, lxix.)

II. *The sensible heat, or temperature of ice, is not changed by liquefaction.*—A thermometer in pounded ice stands at 32°, and at the very same point in the water which results from the liquefaction of ice.

III. *Yet ice, during liquefaction, must absorb much caloric.*—Expose a pound of water at 32°, and a pound of ice at 32°, in a room, the temperature of which is several degrees above the freezing point, and uniformly the same during the experiment. The water will arrive at the temperature of the room, several hours before the ice is melted; and the melted ice will have, as before its liquefaction, the temperature of 32°. Yet the ice must, during the whole of this time, have been imbibing caloric, because (according to Experiment IV. § 1.) a colder body can never be in contact with a warmer one, without receiving caloric from it. The caloric, therefore, which has entered the ice, but is not to be found in it by the thermometer, is said to have *become latent.* As it is the cause of the liquefaction of the ice, it is sometimes called *caloric of fluidity.*

IV. *The quantity of caloric that enters into a pound of ice, and becomes latent, during liquefaction, may be learned by experiment.*—To a pound of water, at 172°, add a pound of ice at 32°. The temperature will not be the arithmetical mean (102°), but much below it, *viz.* 32°. All the excess of caloric in the hot water has therefore disappeared. From 172° take 32°; the remainder, 140°, shows the quantity of caloric that enters into a pound of ice during liquefaction; that is, as much caloric is absorbed by a pound of ice, during its conversion into water, as would raise a pound of water from 32° to 172°.

It is from the property of its uniformly absorbing the same quantity of caloric for conversion into water, that ice has been ingeniously applied, by Lavoisier and Laplace, to the admeasurement of the heat, evolved in certain operations. Let us suppose the body (from which the caloric, evolved either by simple cooling or combustion, is to be measured) to be inclosed in a hollow sphere of ice,

with an opening at the bottom. When thus placed, the heat, which is given out, will be all employed in melting the ice; and will produce this effect in direct proportion to its quantity. Hence the quantity of ice, which is converted into water, will be an accurate measure of the caloric, that is separated from the body submitted to experiment. In this way, Lavoisier ascertained that equal weights of different combustible bodies melt, by burning, very different weights of ice. The apparatus which he employed for this purpose, he has called the *calorimeter*. Its construction can scarcely be understood without the plate, which accompanies the description in his "Elements of Chemistry."

V. *Other examples of the absorption of caloric, during the liquefaction of bodies*, are furnished by the mixture of snow and nitric acid, or of snow and common salt, both of which, in common language, produce intense cold.*

1. Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption, and intimate fixation, of the free caloric of the mixture, by the liquefying snow.

2. Mix quickly together equal weights of fresh-fallen snow at 32°, and of common salt cooled, by exposure to a freezing atmosphere, down to 32°. The two solid bodies, on admixture, will rapidly liquefy; and the thermometer will sink 32°, or to 0; or, according to Sir C. Blagden, to 4° lower. (Philosophical Transactions, lxxviii. 281.) To understand this experiment, it must be recollected, that the snow and salt, though at the freezing tem-

* The extraordinary powers of muriate of lime and snow, in generating cold, will be described hereafter.

perature of water, have each a considerable portion of uncombined caloric. Now, salt has a strong affinity for water; but the union cannot take place while the water continues solid. In order, therefore, to act on the salt, the snow absorbs all the free caloric required for its liquefaction; and during this change, the free caloric, both of the snow and of the salt, amounting to 32°, becomes latent, and is concealed in the solution. This solution remains in a liquid state at 0, or 4° below 0 of Fahrenheit; but if a greater degree of cold be applied to it, the salt separates in a concrete form.

3. Most neutral salts, also, during solution in water, absorb much caloric; and the cold, thus generated, is so intense as to freeze water, and even to congeal mercury. The former experiment, however (*viz.* the congelation of water), may easily be repeated on a summer's day. Add to 32 drachms of water, 11 drachms of muriate of ammonia, 10 of nitrate of potash, and 16 of sulphate of soda, all finely powdered. The salts may be dissolved separately, in the order set down. A thermometer, put into the solution, will show, that the cold produced is at or below freezing; and a little water, in a thin glass tube, being immersed in the solution, will be frozen in a few minutes. Various other freezing mixtures are described in Mr. Walker's papers in the Philosophical Transactions for 1787, 88, 89, 95, and 1801. Of these the table, given in the Appendix, for which I am indebted to the obliging communication of the author, contains an arranged abstract.

4. Muriate of lime, when mixed with snow, produces a most intense degree of cold. This property was discovered some years ago by M. Lowitz, of St. Petersburg, and has been since applied, in this country, to the congelation of mercury on a very extensive scale. The proportions which answer best, are about equal weights of

the salt finely powdered, and of fresh-fallen and light snow. On mixing these together, and immersing a thermometer in the mixture, the mercury sinks with great rapidity. For measuring exactly the cold produced, a spirit-thermometer, graduated to 50° below 0 of Fahrenheit, or still lower, should be employed. A few pounds of the salt are sufficient to congeal a large mass of mercury. By means of 13 pounds of the muriate, and an equal weight of snow, Messrs. Pepys and Allen froze 56 pounds of quicksilver into a solid mass. The mixture of the whole quantity of salt and snow, however, was not made at once, but part was expended in cooling the materials themselves.

On a small scale it may be sufficient to employ two or three pounds of the salt. Let a few ounces of mercury, in a very thin glass retort, be immersed first in a mixture of one pound of each; and when this has ceased to act, let another similar mixture be prepared. The second will never fail to congeal the quicksilver.

The salt thus expended may be again evaporated, and crystallized for future experiments.

The reader, who wishes for farther particulars respecting these experiments, is referred to the Philosophical Magazine, vol. iii. p. 76.

VI. *On the contrary, liquids, in becoming solid, evolve or give out caloric, or, in common language, produce heat.*

1. Water, if kept perfectly free from agitation, may be cooled down several degrees below 32°; but, on shaking it, it immediately congeals, and the temperature rises to 32°.

2. Expose to the atmosphere, when at a temperature below freezing (for example, at 25° of Fahrenheit), two equal quantities of water, in one only of which about a fourth of its weight of common salt has been dissolved. The saline solution will be gradually cooled, without freezing, to 25°. The pure water will gradually descend

to 32°, and will there remain stationary a considerable time before it congeals. Yet while thus stationary, it cannot be doubted, that the pure water is yielding caloric to the atmosphere, equally with the saline solution; for it is impossible that a warmer body can be surrounded by a cooler one, without imparting caloric to the latter. The reason of this equable temperature is well explained by Dr. Crawford. (*On Heat*, p. 80.) Water, he observes, during freezing, is acted upon by two opposite powers: it is deprived of caloric by exposure to a medium, whose temperature is below 32°; and it is supplied with caloric, by the evolution of that principle from itself, *viz.* of that portion which constituted its fluidity. As these powers are exactly equal, the temperature of the water must remain unchanged, till the caloric of fluidity is all evolved.

3. The evolution of caloric, during the congelation of water, is well illustrated by the following experiment of Dr. Crawford:—Into a round tin vessel put a pound of powdered ice; surround this by a mixture of snow and salt in a larger vessel; and stir the ice in the inner one, till its temperature is reduced to + 4° of Fahrenheit. To the ice thus cooled, add a pound of water at 32°. One 5th of this will be frozen; and the temperature of the ice will rise from 4° to 32°. In this instance, the caloric, evolved by the congelation of one 5th of a pound of water, raises the temperature of a pound of ice 28°.

4. If we dissolve sulphate of soda in water, in the proportion of one part to five, and surround the solution by a freezing mixture, it cools gradually down to 31°. The salt, at this point, begins to be deposited, and stops the cooling entirely. This evolution of caloric, during the separation of a salt, is exactly the reverse of what happens during its solution. (Blagden, Philosophical Transactions, lxxviii. 290.)

5. To a saturated solution of sulphate of potash in water, or of any salt that is insoluble in alcohol, add an equal measure of alcohol. The alcohol, attracting the water more strongly than the salt retains it, precipitates the salt, and considerable heat is produced.

Caloric the Cause of Vapour.

I. *Every liquid, when of the same degree of chemical purity, and under equal circumstances of atmospheric pressure, has one peculiar point of temperature, at which it invariably boils.*—Thus, pure water always boils at 212°, alcohol at 176, and ether at 98° Fahrenheit; and, when once brought to the boiling point, no liquid can be made hotter, however long the application of heat be continued. The boiling point of water may be readily ascertained, by immersing a thermometer in water boiling over the fire. As there is some danger in applying heat directly to a vessel containing either ether or alcohol, the ebullition of these fluids may be shown, by immersing the vessel containing them in water, the temperature of which may be gradually raised. The appearance of boiling is owing to the formation of vapour at the bottom of the vessel, and its escape through the heated fluid above it. That the steam, which escapes, is actually formed at the bottom, and not at the top of the water, may be seen by boiling some water in a Florence flask, or other transparent vessel, over an Argand's lamp. The bubbles of vapour will all ascend from the bottom of the vessel.

II. *Steam has exactly the same temperature as boiling water.*—Let a tin vessel be provided, having two holes in its cover, one of which is just large enough to admit the stem of a thermometer. Fill it partly with water, and let the bulb of the thermometer be an inch or two above the surface of the water, leaving the other aperture open

for the escape of vapour. When the water boils, the thermometer, surrounded by steam, will rise to 212°, which is precisely the temperature of the water beneath; yet water, placed on a fire, continues to receive heat, very abundantly, even when boiling hot; and as this heat is not appreciable by the thermometer, it must exist in the steam, in a latent state.

Perfectly formed steam is entirely invisible. We may satisfy ourselves of this by boiling strongly a small quantity of water in a flask; for complete transparency will exist in the upper part of the vessel. It is only when it begins to be condensed, that steam becomes visible. We have a proof also, of the same fact in the thick fogs, which are produced by a sudden transition from warm to cold weather; the vapour, which was imperceptible at the higher temperature, being condensed and rendered visible by the lower.

III. *The boiling point of the same fluid varies, under different degrees of atmospheric pressure.* Thus, water, which has been removed from the fire, and ceased to boil, has its ebullition renewed, when it is placed under a receiver, the air of which is quickly exhausted by an air pump. Alcohol and ether, confined under an exhausted receiver, boil violently at the temperature of the atmosphere. In general, liquids boil *in vacuo*, with about 140° less of heat, than are required under a mean pressure of the atmosphere. (Black's Lectures, i. 151.) Even the ordinary variations in the weight of the air, as measured by the barometer, are sufficient to make a difference in the boiling point of water of about 5° between the two extremes.* On ascending considerable heights, as to the tops of mountains, the boiling point of water gradually

* Sir G. Shuckburgh, in Philosophical Transactions, lxxix. 375.

falls on the scale of the thermometer. Thus on the summit of Mount Blanc, water was found by Saussure to boil at 187° Fahrenheit.*

The influence of a diminished pressure in facilitating ebullition, may be inferred also from the following very simple experiment: Place, over a lamp, a Florence flask, about three 4ths filled with water; let it boil briskly during a few minutes; and, immediately on removing it from the lamp, cork it tightly, and suddenly invert it. The water will now cease to boil; but, on cooling the convex part of the flask by a stream of cold water, the boiling will be renewed. Applying boiling water from the spout of a tea-kettle to the same part of the flask, the water will again cease to boil. This renewal of the ebullition, by the application of cold (an apparent paradox,) is owing to the formation of an imperfect vacuum over the hot water, by the condensation of steam; and the suspension of the boiling, on re-applying the heat, to the renewed pressure on the surface of the hot water, occasioned by the formation of fresh steam.

From these facts, it may be inferred, that the particles of caloric are mutually repulsive, and that they communicate this repulsive tendency to other bodies in which caloric is contained. This repulsive power tends to change solids into fluids, and liquids into aëriform bodies, and is chiefly counteracted by the pressure of the atmosphere.

Were this counteracting cause removed, many bodies, which at present have a liquid form, would cease to be such, and would be changed into a gaseous state. Precisely the same effect, therefore, results from the prevalence of either of these forces. Add to certain liquids a quantity of caloric, in other words, place them in a high

* This furnishes one of the means of measuring the height of mountains.

temperature, and they are immediately converted into gases; or, their temperature remaining the same, diminish the weight of the atmosphere; and the caloric, which they naturally contain, exerts its repulsive tendency with equal effect, and they are in like manner converted into gases. These facts are best shown by the following experiments on ether:

1. Ether, at the temperature of 104°, exists in the state of a gas. This may be shown by filling a jar with water of this temperature, and inverting it in a vessel of the same. Then introduce a little ether, by means of a small glass tube closed at one end. The ether will rise to the top of the jar, and, in its ascent, will be changed into gas, filling the whole jar with a transparent invisible elastic fluid. On permitting the water to cool, the ethereal gas is condensed, and the inverted jar again becomes filled with water.

2. Ether is changed into gas by diminishing the weight of the atmosphere. Into a glass tube, about six inches long, and half an inch in diameter, put a tea-spoonful of ether, and fill up the tube with water; then, pressing the thumb on the open end of the tube, place it, inverted, in a jar of water. Let the whole be set under the receiver of an air pump, and the air exhausted. The ether will be changed into gas, which will expel the water entirely from the tube. On re-admitting the air into the receiver, the gas is again condensed into a liquid form.

IV. *On the contrary, by considerably increasing the pressure, water may be heated to above* 400° *Fahrenheit, without being changed into vapour.* This experiment requires, for its performance, a strong iron vessel, called a Papin's digestor, *" which is an iron boiler holding half

* The lines marked with brackets, I have substituted for Dr. Henry's text, which refers to figures that I cannot give. T. C.

" a gallon or a gallon; with a cover that screws on so " accurately as to be steam-tight. In the cover is a hole, " which may be stopped with a stopper of any kind, as " of cork or soft wood. This stopper is attached to a " lever, of which one end is fastened by a joint or hinge " to the middle of the cover, and on the other end which " projects beyond the cover, weights may be hung as on " the end of a steel-yard. The stopper is kept down by " a pressure, which is measured by the weight suspended " at the end of the lever. In this vessel, steam may be " made nearly red-hot. A thermometer graduated to " 400 degrees, or upwards, may be fixed in the cover, " and secured; but it is not prudent to give a heat beyond " 300 or 350.

" When the barometer is about half way between 29 " and 30, the heat of boiling water is indicated by 212 of " Fahrenheit's thermometer. When the safety valve is " loaded with one atmosphere, or 14lbs. the water will " rise to 240. When, with two atmospheres or 28lbs. it " will raise the mercury to 270 degrees.

" The barometer being as above mentioned, that is, " about the average weight of the atmosphere, the boiling " point of ether is 98° of Fahrenheit: of alcohol of specific " gravity ,825, 176°; water, 212°; oil of turpentine, " 560°; linseed oil, 600°; mercury, 660°.

" According to the experiments of Professor Robison, " a vacuum occasions liquids of whatever kind, to boil " at 145 degrees lower, than they would boil under an at- " mospheric pressure indicated by 30 inches of the baro- " meter. At this rate, water ought to boil in vacuo at 67° " Fahrenheit; but Dr. Thompson found the boiling point " of water under the best vacuum he could make, of " course not a perfect one, 90 degrees.

" It may be useful to state, that according to Achard's " experiments, water saturated with common salt is enab-

" led to receive an addition of heat equal to 10,35°, that " is, water saturated with common salt boils at 222,35, " when it would otherwise boil at 212. If saturated with " sal ammoniac, it boils at 221,79. Borax, sulphat of " magnesia, and sulphat of lime, lowered the boiling point. " These are facts important to the theory of a steam en- " gine."

V. *The absorption of caloric, during evaporation, shown by experiment.*—Moisten a thermometer with alcohol, or with ether, and expose it to the air, repeating these operations alternately. The mercury of the thermometer will sink at each exposure, because the volatile liquor, during evaporation, robs it of its heat. In this way (especially with the aid of an apparatus described by Mr. Cavallo, in the Philosophical transactions, 1781, p. 509), water may be frozen in a thin and small glass ball, by means of ether. The same effect may be obtained, also, by immersing a tube, containing water at the bottom, in a glass of ether, which is to be placed under the receiver of an air pump; or the ether may be allowed to float on the surface of the water. During the exhaustion of the vessel, the ether will evaporate rapidly; and, robbing the water of heat, will completely freeze it; thus exhibiting the singular spectacle of two fluids in contact with each other, one of which is in the act of boiling, and the other of freezing, at the same moment.

VI. *The fixation of caloric in water, by its conversion into steam, may be shewn by the following experiments:* —1. Let a pound of water at 212°, and eight pounds of iron filings at 300°, be suddenly mixed together. A large quantity of vapour will be instantly generated; and the temperature of the mixture will be only 212°; but that of the vapour produced, is also not more than 212°; and the steam must therefore contain, in a latent or combined

form, all the caloric which raised the temperature of eight pounds of iron filings from 212° to 300°.

2. The quantity of caloric, which thus becomes latent during the formation of steam, may be approximated, by repeating the following experiment of Dr. Black: He placed two cylindrical flat bottomed vessels of tin, five inches in diameter, and containing a small quantity of water at 50°, on a red hot iron plate, of the kind used in kitchens. In four minutes the water began to boil, and in twenty minutes the whole was boiled away. In four minutes, therefore, the water received 162° of temperature, or 40½° in each minute. If we suppose, therefore, that the heat continues to enter the water at the same rate, during the whole ebullition, we must conclude that 40½° × 20° = 810 have entered the water, and are contained in the vapour.

It has been found by experiment that 75 pounds of Newcastle coal, or 100 pounds of coal of medium quality, applied in the best manner, are required for the vaporization of 12 cubic feet, or about 89¾ wine gallons of water. A pound of coal, on the average, may be considered as equivalent to convert a gallon of water into vapour.*

VII. *Water, by conversion into steam, has its bulk prodigiously enlarged; viz. according to Mr. Watt's experiments, about* 1800 *times.* A cubic inch of water (or 252 grains) occupies, therefore, when converted into steam, the space of rather more than a cubic foot. Hence its specific gravity, under the ordinary pressure of the air, is to that of common air, nearly as 450 to 1000, or 9 to 20.

* The consumption of coal in Boulton and Watt's steam engine, is about 5½lb. per hour for the power of one horse: that is a power equal to the raising 33000lb. one foot high in a minute.

T. C.

VIII. *On the contrary, vapours, during their conversion into a liquid form, evolve, or give out, much caloric.* The heat given out, by the condensation of steam, is rendered apparent by the following experiment: Mix 100 gallons of water at 50°, with 1 gallon of water at 212°. The temperature of the water will be raised about 1½°. Condense by a common still-tub, 1 gallon of water, from the state of steam, by 100 gallons of water, at the temperature of 50°. The water will be raised 11°. Hence, 1 gallon of water, condensed from steam, raises the temperature of 100 gallons of cold water 9½° more than 1 gallon of boiling water; and, by an easy calculation, it appears, that the caloric imparted to the 100 gallons of cold water by 8 pounds of steam, if it could be condensed in 1 gallon of water, would raise it to 950°. (Black's Lectures, i. 169.)

For exhibiting the same fact, by means of a small apparatus, which may be placed on a table, and with the assitance only of a lamp, the boiler already described (fig.* 46) will be found extremely well adapted. The right angle pipe *e* must be screwed, however, into its place, and must be made to terminate at the bottom of a jar, containing a known quantity of water of a given temperature. This conducting pipe and the jar should be wrapped round with a few folds of flannel. The apparatus being thus disposed, let the water in the boiler be heated by an Argand's lamp, with double concentric wicks, till steam issues in considerable quantity through the cock *c*, which is then to be closed. The steam will now pass through the right angled pipe into the water contained in the jar, which will condense the steam, and will have its temperature very considerably raised. Ascertain the augmentation of temperature and weight; and the result will show, how much a given weight of water has had its tempera-

* I cannot give the figure here. T. C.

ture raised by a certain weight of condensed steam. To another quantity of water, equal, in weight and temperature to that contained in the jar at the outset of the experiment, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparison of the two resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature, than the same quantity of boiling water. This will be better understood by the following example, taken from actual experiment:

Into eight ounces of water, at 50° Fahrenheit, contained in a glass jar, steam was passed from a boiler, till the temperature of the water in the jar rose to 173°. On weighing the water, it was found to have gained $8\frac{1}{2}$ drachms; that is, precisely $8\frac{1}{2}$ drachms of steam had been condensed, and had imparted its heat to the water.* To facilitate the explanation of this experiment, it is necessary to premise the following remarks.

To measure the whole quantities of caloric contained in different bodies, is a problem in chemistry which has not yet been solved. But the quantities of caloric, added to, or substracted from, different bodies (setting out from a given temperature) may, in many cases, be measured and compared with considerable accuracy. Thus, if, as has been already stated, two pounds of water at 120° be mixed with two pounds at 60°, half the excess of caloric in the hot water will pass to the colder portion; that is, the hot water will be cooled 30 , and the cold will re-

* I find the following a convenient method of performing this experiment. In a tin vessel holding a quart, inclosed in another tin vessel and surrounded by an inch of powdered and well dried charcoal, put one pint or 16 oz. by weight of water at the common temperature of the room. Into a small retort put one ounce of water of the same temperature. Evaporate it by a patent lamp, placing the end of the retort in the pint of water. When evaporated try the temperature of the water in the tin vessel. T. C.

ceive 30° of temperature; and if the experiment be conducted with proper precautions, 90°, the arithmetical mean of the temperature of the separate parts, will be the temperature of the mixture. If three pounds of water at 100° be mixed with one pound at 60°, we shall have the same quantity of heat as before, *viz.* four pounds at 90°. Hence, if the quantity of water be multiplied by the temperature, the product will be a comparative measure of the quantity of caloric which the water contains, exceeding the zero of the thermometer employed.

Thus, in the last example,

$3 \times 100 = 300$ = the caloric above zero in the first portion.
$1 \times 60 = 60$ = the caloric above zero in the second do.

The sum, 360 = the caloric above zero in the mixture. Dividing 360 by 4, the whole quantity of water, we obtain 90°, the temperature of the mixture.

This method of computation may be conveniently applied to a variety of cases. Thus, in the foregoing experiment, $8\frac{1}{2}$ drachms of steam at 212°, added to 64 drachms of water at 50°, produced $72\frac{1}{2}$ drachms of water at 173°. Now,

$72\frac{1}{2} \times 173 = 12542\frac{1}{2}$ = whole heat of the mixture.

$64 \times 50 = 3200$ = { heat of 64 drachms, one of the component parts.

$9342\frac{1}{2}$ = { heat of $8\frac{1}{2}$ drachms, the other component part.

Therefore $9342\frac{1}{2}$ divided by $8\frac{1}{2} = 1099$, should have been the temperature of the latter portion (*viz.* $8\frac{1}{2}$ drachms), had none of its heat been latent: and 1099—212 = 887 gives the latent heat of the steam. This result does not differ more than might be expected, owing to the unavoidable inaccuracies of the experiment, from Mr. Watt's determination, which states the latent heat of steam at 900°, or from that to 950°. (Black's Lectures, i. 174.) La-

voisier, with the aid of the calorimeter, makes it 1000° or a little more. (Ibid. 175.)

IX. *The same weight of steam contains, whatever may be its density, the same quantity of caloric; its latent heat being increased in exact proportion as its sensible heat is diminished; and the reverse.*—This principle, though scarcely admitting of illustration by any easy experiment, is one of considerable importance; and an ignorance of it has been the occasion of many fruitless attempts to improve the economy of fuel in the steam engine. The fact, so far as respects steam of lower density than that of 30 inches of mercury, was long ago determined experimentally by Mr. Watt. (Black, i. 190.) As the boiling point of liquids is known to be considerably reduced under a diminished pressure, it seemed reasonable to suspect that, under these circumstances, steam might be obtained from them with a less expenditure of heat. Water, Mr. Watt found, might easily be distilled in vacuo when in the temperature of only 70° Fahrenheit. But, by condensing steam formed at this temperature, and observing the quantity of heat which it communicated to a given weight of water, he determined that its latent heat, instead of being only 950°, was between 1200° and 1300°.

The same principle may be explained, also, by the following illustration, which was suggested to me by Mr. Ewart. Let us suppose that in a cylinder, furnished with a piston, we have a certain quantity of steam, and that it is suddenly compressed, by a stroke of the piston, into half its bulk. None of the steam will in this case be condensed; but it will acquire double elasticity, and its temperature will be considerably increased. Now if we either suppose the cylinder incapable of transmitting heat, or take the moment instantly following the compression before any heat has had time to escape, it must be evident that the sensible and latent heat of the steam, taken toge-

ther before compression, are precisely equal to the sensible and latent heat taken together of the denser steam. But in the dense steam, the sensible heat is increased, and the latent heat proportionally diminished. The explanation of this fact will be furnished by a principle to be hereafter explained, *that the capacities of elastic fluids for caloric are uniformly diminished by increasing their density.*

The large quantity of caloric, latent in steam, renders its application extremely useful for practical purposes. Thus, water may be heated, as in the foregoing experiment, at a considerable distance from the source of heat, by lengthening the conducting pipe *e*. This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of importance to have near the patient's bed room; for the boiler, in which the water is heated, may thus be placed on the ground floor, or in the cellar of a house; and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus.

Specific Caloric.

Equal weights of the *same* body, at the same temperature, contain the same quantities of caloric. But equal weights of *different* bodies, at the same temperature, contain unequal quantities of caloric. The quantity of caloric, which one body contains, compared with that contained in another, is called its *specific caloric;* and the power or property, which enables bodies to retain different quantities of caloric, has been called *capacity for caloric.* The method of determining the specific caloric, or comparative quantities of caloric in different bodies, is as follows:

It has already been observed, that equal weights of the *same* body, at different temperatures, give, on admixture, the arithmetical mean. Thus, the temperature of a pint

of hot water and a pint of cold, is, after mixture, very nearly half way between that of the two extremes. But this is not the case, when equal quantities of *different* bodies, at different temperatures, are employed.

(*a*) If a pint of quicksilver at 100° Fahrenheit, be mixed with a pint of water at 40°, the resulting temperature will not be 70° (the arithmetical mean), but only 60°. Hence the quicksilver loses 40° of heat, which nevertheless raise the temperature of the water only 20°; in other words, a larger quantity of caloric is required to raise the temperature of a pint of water, than that of a pint of mercury, through the same number of degrees. Hence it is inferred, that water has a greater capacity for caloric than is inherent in quicksilver.

(*b*) The experiment may be reversed, by heating the water to a greater degree than the quicksilver. If the water be at 100°, and the mercuryat 40°, the resulting temperature will be nearly 80°; because the pint of hot water contains more caloric, than is necessary to raise the quicksilver to the arithmetical mean.

(*c*) Lastly if we take two measures of quicksilver to one of water, it is of no consequence which is the hotter; for the resulting temperature is always the mean between the two extremes; for example, 70°, if the extremes be 100° and 40°. Here, it is manifest, that the same quantity of caloric, which makes one measure of water warmer by 30°, is sufficient for making two measures of quicksilver warmer by the same number. Quicksilver has, therefore, a less capacity than water for caloric, in the proportion, when equal measures are taken, of one to two.

If, instead of equal *bulks* of quicksilver and water, we had taken equal *weights*, the disparity between the specific caloric of the mercury and water would have been still greater. Thus a pound of water at 100°, mixed with a pound of mercury at 40°, gives a temperature of 97½,

or 27½° above the arithmetical mean. In this experiment, the water, being cooled from 100° to 97½° has lost a quantity of caloric reducing its temperature only 2½°; but this caloric, communicated to the pound of mercury, has produced, in its temperature, a rise of no less than 57½°. Therefore, a quantity of caloric, necessary to raise the temperature of a pound of water 2½°, is sufficient to raise that of a pound of mercury 57½°; or, by the rule of proportion, the caloric, which raises the temperature of a pound of water 1°, will raise that of a pound of quicksilver about 23°. Hence it is inferred, that the quantity of caloric contained in water, is to that contained in the same *weight* of quicksilver as 23° to 1°. Or, stating the caloric of water at 1°, that of quicksilver will be $\frac{1}{23}$ part of 1°, or 0,435*.

When this comparison is extended to a great variety of bodies, they will be found to differ very considerably in their capacities for caloric. The results of numerous experiments of this kind are comprised in a table of specific caloric.

The capacities of bodies for caloric, influence considerably, the rate at which they are heated and cooled. In general, those bodies are most slowly heated, and cool most slowly, which have the greatest capacities for heat.† Thus, if water and quicksilver be set, in similar quantities, and at equal distances before the fire, the quicksilver will be much more rapidly heated than the water; and, on removal from the fire, it will cool with proportionally greater quickness than the water. By ascertaining the comparative rates of cooling, we may even determine, with tolerable exactness, the specific caloric of bodies;

* The above numbers, which differ from those commonly stated, are given on the authority of Mr. Dalton.

† See Martine, on Heat, page 74.

and particularly of one class (the gases), which are not easily compared in any other way. (See Leslie on Heat, chap. xxi.)

ON THE ELASTICITY OF STEAM.*

2 *Gregory's System of Mechanics.*

Since the important invention of the Steam-engine, another species of first movers has come under the consideration of the mechanical investigator, namely, such as arise from the volatilisation of different fluids. Of these the one most commonly chosen is the STEAM raised from hot water, which is an elastic fluid, and which when raised with the ordinary heat of boiling water, is almost 3000 times rarer than water, or more than $3\frac{1}{2}$ times rarer than air, and then has its elasticity equal to that of the common atmospheric air: by great heat it has been found that the steam may be expanded into 14000 times the space of water, and then exerts a force of nearly 5 times the pressure of the atmosphere: and there is no reason to suppose this is the limit: indeed some accidents which have happened, prove clearly, that the elastic force of steam may at least equal that of gunpowder.

The observations on the different degrees of temperature acquired by water in boiling, under different pressures of the atmosphere, and the formation of the vapour from water under the receiver of an air-pump, when with the common temperatures the pressure is diminished to a certain degree, shew clearly that the expansive force of vapour or steam is different in the different temperatures, and that in general it increases in a variable ratio as the temperature is raised. Previous to describing the method which has been adopted to measure the force of steam

* Abridged from Prony's Architecture hydraulique: Prony's account of Betancourt's experiments, Journal de l'Ecole polytechnique: 1 Phil. Mag. 345. T. C.

under different temperatures, it will be proper to describe briefly the method by which the Chemists account for the production of aeriform fluids.

The term *Caloric* is used to denote the cause, whatever it may be, of heat, and of the phenomena which accompany heat: it is now almost universally admitted to be a highly elastic fluid. Every body is according to its nature, capable of containing under a given volume a certain quantity of caloric, either greater or less: this property was first observed by Dr. Black, and the English chemists designated it by the term *Capacity of a body to contain the matter of heat.* Professor Wilcke and M. Lavoisier first made use of the term *specific caloric*, denoting by it the quantity of caloric respectively necessary to elevate to the same number of degrees the temperature of several bodies of equal weight.

Substances volatilised and reduced to *gas* or aeriform fluids, are nothing else than ordinary solid or fluid bodies which by some circumstance are found superabundantly combined with caloric, in such a manner that the constituent particles of these bodies are separated the one from the other, by a quantity of ambient caloric much more considerable than that which surrounds the same particles in the natural state of the bodies. The extreme elasticity of the caloric the effect of which is augmented by its condensation, and the weakening of the reciprocal attraction or of the cohesion of the particles of the bodies (a weakening or diminution produced by the increased distance of those particles) concur to diminish the density of the bodies in such a manner that they become reduced to an aeriform state.

As to the elasticity of gaseous fluids thus formed, it appears in great measure to be produced by the elasticity of caloric itself, which, when bodies are reduced to the gaseous state; occupy a very great part of their volume.

This eminent elasticity of caloric tends continually to produce expansion; on the other hand, this fluid, by a particular destination of nature, is more or less disseminated between the moleculæ of all bodies, in such sort that we may say with M. Lavoisier that even in the solid state these moleculæ do not touch, but, as it were, *swim* in the caloric at a certain distance from each other. There must, therefore, be a perpetual contest between the expansive force of caloric which tends to disseminate the moleculæ, and the cohesive attraction of the moleculæ which tends to join them together. From the reciprocal intensity of these two powers results the solid and liquid states of bodies: thus, water only differs from ice by the greater or less condensation of caloric, which permits more or less of the moleculæ of the liquid to yield to the effect of their attraction or reciprocal cohesion.

When substances pass from the liquid to the aeriform state, there is a third power to combine with the expansive effort of caloric, and the aggregative or attractive effort of the moleculæ; namely, the pressure of the atmosphere, or of any elastic fluid whatever which compresses the fluid, and opposes itself to the separation of its parts. This third power has a certain influence also upon the passage from the solid to the fluid state, but it is most frequently (in this case) very small, and even evanescent in comparison of the resistance arising from the mutual cohesion of the moleculæ. The contrary effect has place in the course of the passage from the liquid to the gaseous or aeriform state; the cohesion of the fluid moleculæ being extremely small, the elasticity of the caloric has scarcely any thing to surmount to produce volatilisation besides the pressure of the atmosphere, or gas which actually compresses it.

Hence it results that the same liquid under different pressures ought to volatilise at different temperatures. M. Lavoisier proved the truth of this result, by placing ether

under the receiver of an air-pump and producing volatilisation solely by taking off a part of the pressure of the atmosphere. See *Chymie, tome I. pa.* 9. And we know by many expriments of M. De Luc and others, that water boils the more speedily as it is less pressed by the weight of the atmosphere.

Lavoisier notices a curious consequence of what has been here said; which is, that if our planet revolved upon its axis, with such a velocity as to lessen the pressure of the atmosphere, or if the temperature of the air were raised, then several fluids which we now see under a liquid state would only exist in the aeriform state; for example, if under the temperature of summer the pressure of the atmosphere were only equivalent to 20 or 24 inches of the barometrical tube, that pressure would not retain Ether in the fluid state, it would be changed into gas; and the like would happen, if while the pressure of the air was equivalent to 28 or 30 inches of the mercury the habitual temperature were 105 or 110 degrees on Fahrenheit's scale.

The principles which have been here exhibited are sufficient for the undestanding of all which relates to the action of water or other fluids reduced to vapour. Now, it has appeared from frequent experiments that water heated in common air volatilises at 80° of Reaumur's thermometer, or 212° of Fahrenheit's, the height of the barometer being 28 French, or 29·9 English inches: and spirits of wine under a like pressure volatilises at between 63° and 64°of Reaumur, or nearly 175° of Fahrenheit. The expansive force of the vapour must, therefore, in both these cases, according to the principles just explained, be measured by a column of mercury of 28 French, or 29·9 English inches, in like manner as such a column measures the pressure of the atmosphere, or the ealasticity of common air. And at any more elevated temperatures the elastic force of the vapour will surpass the pressure of the

atmosphere by a quantity which has a certain relation with the excess of the temperature above those just stated.

Till lately there was wanting on this important subject series of exact and direct experiments by means of which, having given the temperature of the heated fluid, the expansive force of the steam rising from it might be known, and *vice versa.* There was likewise wanting an analytical theorem expressing the relation between the temperature of the heated fluid and the pressure with which the force of the steam was in equilibrio. These desiderata have, however, been lately supplied by M. Bettancourt, an ingenious Spanish philosopher, after a method which we shall now concisely explain.*

M. Bettancourt's apparatus consists of a copper vessel or boiler, with its cover firmly soldered on: this cover has three orifices which close up with screws: at the first the water or other fluid is put in and out; through the second passes the stem of a thermometer which has the whole of its scale or graduations above the vessel, and its ball within, where it is immersed either in the fluid or in the steam according to the different circumstances; through the third hole passes a tube, making a communication between the cavity of the boiler and one branch of an inverted syphon, which contains mercury, and acts as a barometer for measuring the pressure of the elastic vapour within the boiler. In the side of the vessel there is a fourth hole into which is inserted a tube with a turn-cock, making a communication with the receiver of an air-pump, in order to extract the air from the boiler and to prevent its return.

The apparatus being prepared in good order, and distilled water introduced into the boiler at the first hole, and then stopped, as well as the end of the inverted syphon or barometer, M. Bettancourt surrounded the boiler with ice,

* See 1 Phil. Mag. 345. T. C.

to lower the temperature of the water to the freezing point, and then, having extracted all the air from the boiler by means of the air-pump, the difference between the columns of mercury in the two branches of the barometer shewed the measure of the elastic force of the vapour arising from the water in that temperature. Then lighting the fire below the boiler, he gradually raised the temperature of the water from 0 to 110° of Reaumur's thermometer, that is, from 32° to 279½° of Fahrenheit's thermometer; and for each degree of elevation in the temperature he observed the height of the mercurial column which measured the elasticity or pressure of the vapour.

These experiments were repeated various times and with different quantities of water in the vessel; their results were arranged in different columns for the sake of comparison, and it appeared that the pressures for different temperatures agreed very nearly, however much the quantity of fluid in the vessel was varied. It was also seen that the increase in the expansive force of the vapour is at first very slow; but increases gradually unto the higher temperatures, where the increase becomes very rapid, as will be obvious from an examination of the tables in some of the following pages.

To express the relation between the degrees of temperature of the vapour and its elastic force, this philosopher employs a method suggested by M. Prony, which consists in imagining the heights of the columns of mercury measuring the expansive force to represent the ordinates of a curve, and the degrees of heat the corresponding abscissæ of that curve; making the ordinates equal to the sum of several logarithmic ones which contain two indeterminates, and ascertaining these quantities in such manner that the curve may agree with a tolerable number of observations taken throughout the whole extent of the change of temperature, from the lowest to the highest extreme of the experiments. Then a formula or equation

to a curve is investigated, and when the curve corresponding to that equation is constructed, if it coincide (with the exception of a few trifling anomalies) with the curve constructed by the results of the experiments, the formula may be looked upon as correct, and furnishing a true analytical representation of the phenomena. This was done by M. Bettancourt, and the curve constructed from this equation has a point of inflexion at about the 102° of Reaumur,* as it ought to have, because the second differences of the barometrical measures of the elastic force became negative at that temperature.

In a similar manner M. Bett ancourt made experiments on the strength of the vapour from alcohol of spirit of wine; constructing the curve and deducing the requisite analytical formula. This curve had likewise a point of inflexion at about 88° of Reaumur, the second differences in the table of barometrical measures becoming then negative. From a comparison of the experiments on the vapour of water with those on the vapour of alcohol, a remarkable conclusion was derived: for it appeared that, after the first 20° of Reaumur, the strength of the vapour of spirit of wine was to that of the vapour of water, nearly in the same constant ratio of 23 to 10, or 7 to 3, for any one and the same degree of heat. Thus, at the temperature of 40° of Reaumur, the strength of the steam of water is measured by 2·9711 Paris inches in the barometer, and that of vapour of alcohol by 6·9770, the latter being about 2⅓ times the former.

The equations to the curve of temperature and pressure, denoting the relation between the abscissæ and ordinates, or between the temperature and the elasticity of the vapour, as given by M. Bettancourt, were of the following form.

* To convert Reau. into Fah. multiply Reau. by 9, divide by 4: add to the quotient 32 and the sum is Fah. Reaum. $\frac{\times 9}{4} + 32 = \text{Fah}$

$$y = \begin{matrix} m+lx & m'+l'x & sx-r & s'x-r' \\ e & -e & -e & +e \\ m+lx & m'+lx & sx-r & s'x-r' \end{matrix}$$

1. For water,
2. — alcohol, $y = e \quad +e \quad -e \quad +e \quad -A.$

Where y represents the height of the column of mercury which measures the expansive force, x the corresponding degrees of Reaumur's thermometer, and the other letters certain values which are assigned to them in the investigation.

But M. Prony, in the 2d volume of his *Architecture Hydraulique*, has thrown these equations into a rather more convenient form, though analogous to those of Bettancourt. His formula for the vapour of water is this,

$$y = m_{,} r_{,}^{x} + m_{,,} r_{,,}^{x} + m_{,,,} r_{,,,}^{x} + m\text{iv } r\text{iv}^{x}.$$

The method which he followed consisted in satisfying the results between 0° and 80°, by means of the two first terms, and to interpolate by means of the other two, the differences between the observed values, and those computed by the two first terms, from 80° up to 110°. In this manner he succeeded to express so exactly the observations in their whole extent, that the curves of the calculus and the experiments were only distinguishable the one from the other by such little anomalies, as were manifestly the effect of some trifling though inevitable errors in the observations, and in the graduations of the scales in the apparatus. He afterwards employed an equation of three terms, giving to the different coefficients the following values :

$r_{,}$	$= 1{\cdot}172805$	log. $r_{,}$	$= 0{\cdot}0692259$
$r_{,,}$	$= 1{\cdot}047773$	log. $r_{,,}$	$= 0{\cdot}0202661$
$r_{,,,}$	$= 1{\cdot}028189$	log. $r_{,,,}$	$= 0{\cdot}0120736$
$m_{,}$	$= -0{\cdot}00000072460407$	log. $m_{,}$	$= \overline{7}{\cdot}8601007$
$m_{,,}$	$= +0{\cdot}8648188803$	log. $m_{,,}$	$= \overline{1}{\cdot}9369271$
$m_{,,,}$	$= -0{\cdot}8648181057$	log. $m_{,,,}$	$= \overline{1}{\cdot}9369248$

Substituting these several values in the equation

$$y = m_{,} r_{,}^{x} + m_{,,} r_{,,}^{x} + m_{,,,} r_{,,,}^{x},$$

it satisfies not only the numbers employed in its formation, but all the intermediate observations, as may be concluded from the following table, which exhibits to every 10 degrees of Reaumur's thermometer the barometrical results both of observation and the calculus.*

Temperature.	Pressures given by		Anomalies.
	Experim.	Calculus.	
0	0·00in.	0·00in.	0·00 in.
10	0·15	0·24	+0·09
20	0·65	0.69	+0·04
30	1·52	1·51	--0·01
40	2·92	2·95	+0·03
50	5·35	5·42	+0·07
60	9·95	9·62	--0·33
70	16·90	16·57	--0·33
80	28·00	27·92	--0·08
90	46·40	45·87	--0·53
100	71·80	71·94	+0·14
110	98·00	98·36	+0·36

The anomalies are generally much more minute than in the formulæ of four terms: we may therefore regard

* *Table of the Force of Steam at different Temperatures of Fahrenheit's Scale from actual Experiment.* 2 *Hen. Ch.* 518.

(Bettancourt in Prony's Architecture Hydraulique.)

Temperature.	Force in English Inches of Mercury.	Temperature.	Force in English Inches of Mercury.
32	0	162	9.07
42	.08	172	11.0
52	.21	182	14.9
62	.38	192	18.7
72	.58	202	23.7
82	.87	212	29.8
92	1.26	222	37.4
102	1.74	232	46.5
112	2.37	242	57.3
122	3.16	252	69.7
132	4.16	262	83.6
142	5.43	272	97.1
152	7.00	282	108.

the equation just preceding the table, which is more simple than that of Bettancourt, as representing the phenomena and measuring the effects of the expansive force of the steam of water with all desirable accuracy. M. Prony remarks, that the smallness of the coefficient m, will allow the term $m_{,} r_{,}^{x}$ to be neglected in reckoning between 0° and 80°; and thus from the temperature of ice up to that of boiling water, the equation of two terms alone will suffice, that is to say .... $y = m_{,,} r_{,,}^{x} + m_{,,,} r_{,,,}^{x}$.

M. Prony's equation for the vapour of alcohol comprises 5 terms originally: but in most cases three of those terms will give results sufficiently accurate. The numeral values of the coefficients are as below:

$r_{,} = 1{\cdot}11424$ - - - -	log. $r_{,} = 0{\cdot}04697771$
$r_{,,} = 1{\cdot}05714$ - - - -	log. $r_{,,} = 0{\cdot}02413079$
$r_{,,,} = 0{\cdot}79943$ - - - -	log. $r_{,,,} = \overline{1}{\cdot}9027776$
$m_{,} = -0{\cdot}0021293$ - - -	log. $m_{,} = \overline{3}{\cdot}3282330$
$m_{,,} = +0{\cdot}9116186$ - - -	log. $m_{,,} = \overline{1}{\cdot}9598132$
$m_{,,,} = +0{\cdot}2097778$ - - -	log. $m_{,,,} = \overline{1}{\cdot}3217595$
miv $= -1{\cdot}1192671$	

These numbers cause the experiments and calculus to coincide very nearly, when introduced into the equation

$$y = m_{,} r_{,}^{x} + m_{,,} r_{,,}^{x} + m_{,,,} r_{,,,}^{x} + \text{miv}.$$

The magnitude of the anomalies will be seen by inspecting the following table.

Temperature.	Pressures given by		Anomalies.
	Experim.	Calculus.	
0	0·00in.	0·00in.	0·00
10	0·47	0·45	−0·02
20	1·52	1·56	+0·04
30	3·49	3·54	+0·05
40	6·90	6·97	+0·07
50	13·05	12·93	−0·12
60	23·65	23·05	−0·50
70	39·30	39·31	+0·01
80	63·80	64·35	+0·55
90	98·00	98·28	+0·28

Thus the formula for the vapour of spirit of wine is found as simple as that for the vapour of water, without ceasing to represent the experiments with all desirable exactness. But more than this, we may retrench one of the variable terms; for in the first degree $m_{,,,} r_{,,,}{}^{x}$ has no greater value than 0·18, and when x is 2, 3, or any other positive value, this third term may be safely neglected. The equation therefore is reduced to

$$y = m_{,} r_{,}{}^{x} + m_{,,} r_{,,}{}^{x} + \text{miv};$$

a form much more simple than Bettancourt's original equation, and indeed more simple than Prony's improved equation for the vapour of water.

To save the trouble of investigating the strength of the vapour by these formula for every separate case that may occur, we add a table (calculated from these principles) in which the strength of the vapour both of water and of spirit of wine is shewn for every degree of Reaumur's thermometer up to 110°, or for every $2\frac{1}{4}$ degrees of Fahrenheit, from 32 to 280°: the strengths are expressed, not in English or in French inches upon the barometer, but in terms, whose unit is the medium pressure of the atmosphere, supposing that medium equivalent to 29·9

English, or 28 French inches of mercury. The pressure upon a square inch in pounds avoirdupois corresponding to any temperature may be found by multiplying the corresponding number taken from the table by 4·5: and the pressure for any intermediate degree of Fahrenheit may be found pretty nearly, by proportioning, as is usual in tables of Logarithms, &c.

Degrees of Thermometer		Pressure in terms of atmospheric pressure.		Degrees of Thermometer		Pressure in terms of atmospheric pressure.	
Reau.	Fahr.	Vapour of Water	Vapour of Alcohol.	Reau.	Fahr.	Vapour of Water.	Vapour of Alcohol.
1	34¼	·00063	·00015	33	106¼	·06668	·15656
2	36½	·00124	·00074	34	108½	·07136	·16771
3	38¾	·00192	·00171	35	110¾	·07634	·17949
4	41	·00267	·00299	36	113	·08159	·19193
5	43¼	·00371	·00449	37	115¼	·08714	·20151
6	45½	·00433	·00641	38	117½	·09302	·21898
7	47¾	·00539	·00849	39	119¾	·09921	·23366
8	50	·00621	·01080	40	122	·10611	·24921
9	52¼	·00740	·01333	41	124¼	·11266	·26557
10	54½	·00823	·01608	42	126½	·11994	·28289
11	56¾	·00971	·01832	43	128¾	·12762	·30120
12	59	·01085	·02163	44	131	·13573	·32054
13	61¼	·01221	·02514	45	133¼	·14428	·34098
14	63½	·01384	·02884	46	135½	·15329	·36256
15	65¾	·01521	·03276	47	137¾	·16279	·38538
16	68	·01706	·03689	48	140	·17281	·40931
17	70¼	·01860	·04126	49	142¼	·18338	·43500
18	72½	·02046	·04588	50	144½	·19447	·46193
19	74¾	·02244	·05076	51	146¾	·20609	·49036
20	77	·02454	·05591	52	149	·21855	·52043
21	79¼	·02677	·06136	53	151¼	·23155	·55218
22	81½	·02914	·06711	54	153½	·24524	·58571
23	83¾	·03165	·07319	55	155¾	·25228	·62117
24	86	·03432	·07961	56	158	·27481	·65864
25	88¼	·03715	·08641	57	160¼	·29076	·69671
26	90½	·04014	·09358	58	162½	·30650	·73673
27	92¾	·04331	·10116	59	164¾	·32525	·77167
28	95	·04667	·10917	60	167	·34386	·82337
29	97¼	·05023	·11763	61	169¼	·36345	·86946
30	99½	·05364	·12657	62	171½	·38249	·91467
31	101¾	·05833	·13603	63	173¾	·40572	·96587
32	104	·06219	·14601	64	176	·42849	1·0231

Degrees of Thermometer.		Pressure in terms of atmospheric pressure.		Degrees of Thermometer.		Pressure in terms of atmospheric pressure.	
Reau.	Fahr.	Vapour of Water.	Vapour of Alcohol.	Reau.	Fahr.	Vapour of Water.	Vapour of Alcohol.
65	178¼	·45245	1·0795	88	230	1·4872	3·2548
66	180½	·47765	1·1385	89	232¼	1·5618	3·3806
67	182¾	·50414	1·2004	90	234½	1·6382	3·5099
68	185	·53199	1·2652	91	236¾	1·7176	
69	187¼	·56126	1·3330	92	239	1·8003	
70	189½	·59203	1·4038	93	241¼	1·8851	
71	191¾	·62436	1·4778	94	243½	1·9733	
72	194	·65832	1·5552	95	245¾	2·0643	
73	196¼	·69403	1·6359	96	248	2·1579	
74	198½	·74589	1·7199	97	250¼	2·2539	
75	200¾	·77096	1·8075	98	252½	2·3527	
76	203	·81236	1·8985	99	254¾	2·4533	
77	205¼	·85588	1·9932	100	257	2·5554	
78	207½	·90214	2·0855	101	259¼	2·6587	
79	209¾	·94957	2·1895	102	261½	2·7628	
80	212	1·0000	2·2983	103	263¾	2·8667	
81	214¼	1·0519	2·4074	104	266	2·9735	
82	216½	1·1064	2·5177	105	268¼	3·0711	
83	218¾	1·1634	2·6345	106	270½	3·1691	
84	221	1·2232	2·7527	107	272¾	3·2631	
85	223¼	1·2851	2·8739	108	275	3·3505	
86	225½	1·3500	2·9977	109	277¼	3·4299	
87	227¾	1·4177	3·1236	110	279½	3·5127	

Several curious and in some respects useful consequences might be deduced from these experiments and theorems. M. Bettancourt shews for instance, that the effect of steam engines must, in general, be greater in winter than in summer, owing to the different degrees of temperature in the water of injection. And from the greatly superior strength of the vapour of spirit of wine over that of water, he argues that, by trying other fluids, some may be found, not very expensive, whose vapour may be so much stronger than that of water, with the same degree of heat, that it may be substituted instead of water in the boilers of steam engines, to the great saving in the expence of fuel: nay, he even asserts, that spirit of wine itself might thus be employed in a machine of a

particular construction, which, with the same quantity of fuel, and without any increase of expence in other things, shall produce an effect far superior to what is obtained from the steam of water. Another use of these researches suggested by M. Bettancourt is, to measure the height of mountains by means of a thermometer immersed in boiling water; which he thinks may be done with a precision equal, if not superior, to that of the barometer. But this, being foreign to our present enquiries, cannot be entered upon here: a comparison of the results of this method with some deduced from the more customary process may be seen in Dr. Hutton's Dictionary, vol. II. pa. 756, to which such as are desirous of further information on this point are referred.

Our ingenious countryman Mr. Dalton, of Manchester, is of opinion that M. Bettancourt's deductions are not quite accurate. His chief error consists in having assumed the force of vapour from water of 32° (Fahrenheit) to be nothing; which makes his numbers essentially wrong at that point and in all the lower parts of the scale: and in the higher part, or that which is above 212°, the force is determined too much; owing as Mr. Dalton apprehends, to a quantity of air, which being disengaged from the water by heat and mixing with the steam, increases the elasticity.

Mr. Dalton's first experiments with spirit of wine led him to adopt the same conclusion as M. Bettancourt, with respect to the constant ratio between the force of the vapour from this spirit and that from water; and inferred the same with regard to the vapour from other fluids. But, on pursuing the subject, he concluded that this principle was not true, either with respect to spirit of wine or any other liquid. His experiments upon six different liquids agree in establishing as a general law, "*That the "variation of the force of vapour from all liquids is the*

" *same for the same variation of temperature, reckoning* " *from vapour of any given force:* thus, assuming a force " equal to thirty inches of mercury as the standard, it be- " ing the force of vapour from any liquid boiling in the " open air, we find *aqeous* vapour loses half its force by a " diminution of 30 degrees of temperature: so does the " vapour of any other liquid lose half its force by dimi- " nishing its temperature 30 degrees below that in which " it boils; and the like for any other increment or decre- " ment of heat. This being the case, it becomes unneces- " sary to give distinct tables of the force of vapour from " different liquids, as one and the same table is sufficient " for all."

The experiments on which this conclusion rests, are related in the fifth volume of the *Manchester Memoirs:* they may also be seen in the 6th volume of the New Series of *Mr. Nicholson's Journal.* Mr. Dalton has calculated a table of the force of vapour of water from the temperature of 40° below zero of Fahrenheit, to 325° above it. From this table we have extracted the following; in which we have, as before, reduced the force to the medium pressure of the atmosphere for the measuring unit, that the small differences in the results of the English and the Spanish philosopher may be the more readily traced.

Temperature on Fahr.	Force of aqueous Vapour.	Temperature on Fahr.	Force of aqueous Vapour
80°	·0333	212°	1·000
90	·0453	220	1·166
100	·0620	230	1·391
110	·0843	240	1·655
120	·1110	250	1·940
130	·1446	260	2·257
140	·1913	270	2·595
150	·2473	280	2.958
160	·3153	290	3·337
170	·4043	300	3·727
180	·5050	310	4·117
190	·6333	315	4·309
200	·7880	320	4·500
210	·9613	325	4·690

The preceding experiments and calculations of Bettancourt, are certainly valuable; but they require to be checked by the very important paper of Mr. Dalton, of Manchester, of which the following is an extract so far as it relates immediately to the theory of the Steam Engine.

Extract from experimental Essays on the Constitution of mixed Gases; on the force of steam or vapour from water and other liquids in different temperatures, both in a Torricellian Vacuum and in air; on evaporation; and on the expansion of gases by heat. By JOHN DALTON. 5 Manch. Trans. 241. 6 Nich. Phil. 257.

THE progress of Philosophical knowledge is advanced by the discovery of new and important facts; but much more when those facts lead to the establishment of *general*

laws. It is of importance to understand that the descent of falling bodies is the same every where on the surface of the earth; but from that and some other particular facts to infer the law of gravitation, or that all matter attracts with a force decreasing as the square of the distance, is a much higher attainment in science. In the train of experiments lately engaging my attention some new facts have been ascertained, which, with others, seem to authorise the deduction of general laws, and such as will have influence in various departments of natural philosophy and chemistry.

As the detail of experiments will be best understood and their application seen, if the laws of principles alluded to be kept in view, it may be proper here to state them; though it must not be understood that they were proceeded upon hypothetically in the direction of those experiments. On the contrary, the first law, which is as a mirror in which all the experiments are best viewed, was *last* detected, and after all the particular facts had been previously ascertained.

1. When two elastic fluids, denoted by *A* and *B*, are mixed together, there is no mutual repulsion amongst their particles; that is, the particles of *A* do not repel those of *B*, as they do one another. Consequently, the pressure or whole weight upon any one particle arises solely from those of its own kind.

2. The force of steam from all liquids is the same, at equal distances above or below the several temperatures at which they boil in the open air: and that force is the same under any pressure of another elastic fluid as it is in vacuo. Thus, the force of *aqueous* vapour of 212° is equal to 30 inches of mercury; at 30° below, or 182°, it is of half that force; and at 40° above, or 252°, it is of double the force; so likewise the vapour from sulphuric ether which boils at 102°, then supporting 30 inches of mercu-

ry, at 30° below that temperature it has half the force, and at 40° above it, double the force: and so in other liquids. Moreover, the force of aqueous vapour of 60° is nearly equal to half inch of mercury, when admitted into a torricellian vacuum; and water of the same temperature, confined with perfectly dry air, increases the elasticity to just the same amount.

3. The quantity of any liquid evaporated in the open air is directly as the force of steam from such liquid at its temperature, all other circumstances being the same.

4. All elastic fluids expand the same quantity by heat: and this expansion is very nearly in the same equable way as that of mercury; at least from 32° to 212°.—It seems probable the expansion of each particle of the same fluid, or its sphere of influence, is directly as the quantity of heat combined with it; and consequently the expansion of the fluid as the cube of the temperature, reckoned from the point of total privation.

Having now stated the chief principles which seem to be established from the following series of facts and observations, I shall proceed to treat of them under the several heads.

On the force of steam or vapour from water and various other liquids, both in a vacuum and in air.

The term *steam* or *vapour* is equally applied to those elastic fluids which, by cold and pressure of certain known degrees, are reduced wholly or in part into a liquid state. Such are the elastic fluids arising from water, alcohol, ether, ammonia, mercury, &c. Other elastic fluids that cannot be reduced, or rather that have not yet been reduced, into a liquid state by the united agency of those two powers, are commonly denominated *gases*. There can scarcely be a doubt entertained respecting the reducibility

of all elastic fluids of whatever kind into liquids; and we ought not to despair of effecting it in low temperatures and by strong pressure exerted upon the unmixed gases. However unessential the distinction between the gases and vapours may be in a chemical sense, their *mechanical* action is very different. By increasing the quantity of any gas in a given space the force of it is proportionally increased; but increasing the quantity of any liquid in a given space does not at all affect the force of the vapour arising from it. On the other hand, by increasing the temperature of any gas a proportionate increase of elasticity ensues; but when the temperature of a liquid is increased, the force of vapour from it is increased with amazing rapidity, the increments of elasticity forming a kind of geometrical progression, to the arithmetical increments of heat.—Thus, the ratio of the elastic force of atmospheric air of 32°, to that at 212°, is nearly as 5 : 7; but the ratio of the force of aqueous vapour proceeding from water of 32° and 212°, is as 1 : 150 nearly.

The object of the present essay is to determine the utmost force that certain vapours, as that from water, can exert at different temperatures. The importance hitherto attached to this enquiry has arisen chiefly from the consideration of steam as a mechanical agent; and this has directed the attention more especially to high temperatures. But it will appear from what follows that the progress of philosophy is more immediately interested in accurate observations on the force of steam in low temperatures. Different authors have published accounts of their experiments on the force of steam: I have on a former occasion (Meteorological Essays, page 134) given a table of forces for every 10° from 80° to 212°. The author of the article "Steam," in the Encyclopedia Britannica, has done the same from 32° to 280°: and M. Bettancourt, in the "Memoirs des scavans etrangeres" for 1790, (see Hut-

ton's Math. Diction. page 755) has given tables on the subject, both for vapour from water and spirit of wine, also from 32° to 280°. But these two authors, having assumed the force of vapour from water of 32° to be nothing, are essentially wrong at that point and in all the lower parts of the scale; and in the higher part, or that above 212°, they determine the force too much: owing as I apprehend to a quantity of air, which being disengaged from the water by heat and mixing with the steam, increases the elasticity.—In a question of such moment it seemed therefore desirable to obtain greater accuracy.

My method is this: I take a barometer tube perfectly dry, and fill it with mercury just boiled, marking the place where it is stationary; then having graduated the tube into inches and tenths by means of a file, I pour a little water (or any other liquid the subject of experiment) into it, so as to moisten the whole inside; after this I again pour in mercury, and, carefully inverting the tube, exclude all air: the barometer by standing some time exhibits a portion of water, &c. of $\frac{1}{8}$ or $\frac{1}{10}$ of an inch upon the top of the mercurial column; because being lighter it ascends by the side of the tube; which may now be inclined and the mercury will rise to the top manifesting a perfect vacuum from air. I next take a cylindrical glass tube open at both ends, of 2 inches diameter and 14 inches in length; to each end of which a cork is adapted, perforated in the middle so as to admit the barometer tube to be pushed through and to be held fast by them; the upper cork is fixed two or three inches below the top of the tube, and is half cut away so as to admit water, &c. to pass by; its service being merely to keep the tube steady. Things being thus circumstanced, water of any temperature may be poured into the wide tube, and thus made to surround the upper part or vacuum of the barometer, and the effect of temperature in the production of vapour

within can be observed from the depression of the mercurial column. In this way I have had water as high as 155° surrounding the vacuum: but as the higher temperatures might endanger a glass apparatus; instead of it I used the following:—

Having procured a tin tube of four inches in diameter and two feet long, with a circular plate of the same soldered to one end having a round tube in the centre like the tube of a reflecting telescope, I got another smaller tube of the same length soldered into the larger, so as to be in the axis or centre of it: the small tube was open at both ends, and on this construction water could be poured into the large vessel to fill it, whilst the central tube was exposed to its temperature. Into this central tube I could insert the upper half of a syphon barometer, and fix it by a cork, the top of the narrow tube also being corked; thus the effect of any temperature under 212° could be ascertained, the depression of the mercurial column being known by the ascent in the exterior leg of the syphon.

The force of vapour from water between 80° and 212° may also be determined by means of an air-pump; and the results exactly agree with those determined as above. Take a Florence flask half filled with hot water, into which insert the bulb of a thermometer; then cover the whole with a receiver on one of the pump-plates, and place a barometer gage on the other: the air being slowly exhausted, mark both the thermometer and barometer at the moment ebullition commences, and the height of the barometer gage will denote the force of vapour from water of the observed temperature. This method may also be used for other liquids. It may be proper to observe, the various thermometers used in these experiments were duly adjusted to a good standard one.

After repeated experiments by all these methods, and a careful comparison of the results, I was enabled to digest the following table of the force of steam from water in all the temperatures from 32° to 212°.

Two important enquiries still remained, the first to determine the force of steam from water above 212° and below 32°; the second, to determine the comparative forces of vapour from other liquids. These enquiries seemed independent of each other; notwithstanding which I found them in reality connected.

Upon examination of the numbers in the table, within the limits just mentioned, there appears something like a geometrical progression in the forces of vapour; the ratio, however, instead of being constant, is a gradually diminishing one: thus the

Force at 32° = ,200 inch.

17. 50
122 = 3. 500 } Ratios.
8. 57

212 = 30. 000

If we divide these ratios, according to observation, they will stand thus:

Force at 32° = ,200 inch.

4. 550
77 = ,910
3. 846
122 = 3. 500 } Ratios.
3. 214
167 = 11. 250
2. 666

212 = 30. 000

If we divide these again they become,

Force at	32° =	,200	inch.
			2. 17
	54½ =	,435	
			2. 09
	77 =	910	
			2. 00
	99½ =	1. 820	
			1. 92
	122 =	3. 500	Ratios.
			1. 84
	144½ =	6. 450	
			1. 75
	167 =	11. 250	
			1. 67
	189½ =	18. 800	
			1. 59
	212 =	30. 000	

By another division we obtain the ratios for every 11½° of temperature from 32° to 212°, as under:

Force at	32° =	,200	inch
			1. 485
	43¾ =	,297	
			1. 465
	54½ =	,435	
			1. 45
	65¼ =	,630	
			1. 44
	77 =	,910	
			1. 43
	88¼ =	1. 290	
			1. 41
	99½ =	1. 820	
			1. 40
	110¾ =	2. 540	
			1. 38
	122 =	3. 500	Ratios.
			1. 36
	133¼ =	4. 760	
			1. 35
	144½ =	6. 450	

		1. 33
$155\frac{1}{4}$	= 8. 550	
		1. 32
167	= 11. 250	
		1. 30
$178\frac{1}{4}$	= 14. 600	
		1. 29
$139\frac{1}{2}$	= 18. 800	
		1. 27
$200\frac{1}{4}$	= 24. 000	
		1. 25
212	= 30. 000	

Thus it appears that a ratio having a uniform decrease nearly takes place; and we may therefore extend the table of forces at both extremes, without the aid of experiment, to a considerable distance. Thus assuming the ratios for each interval of a $11\frac{1}{4}°$ below 32° to be, 1.500, 1.515, 1.530, 1.545, &c. and for each interval above 212° to be 1.235, 1.220, 1.205, 1.190, 1.175, 1.160, 1.145, 1.130, &c. we can extend the table many intervals of temperature, and determine all the intermediate degrees by interpolation. This method may be relied upon as a near approximation; however it does not supercede the expediency of determination by experiment; though that is much more difficult above 212°, and below 32°, than in the intermediate degrees; because it is difficult to procure a steady heat above 212°; and below 32° the variation of force becomes so small as to elude minute discrimination. It will appear from what follows that the extension of the table by this method above 212° is in all probability accurate, or very nearly so, for 100° or more.

Table of the force of vapour from water in every temperature from that of the congelation of mercury, or 40° below zero of Fahrenheit, to 325°.

Temperature.	Force of vap. in inches of mercury.	Temperature.	Force of vap. in inches of mercury.	Temperature.	Force of vap. in inches of mercury.
-40°	,013	36°	,229	78°	,940
-30	,020	37	,237	79	,971
-20	,030	38	,245	80	1. 00
-10	,043	39	,254	81	1. 04
—	—	40	,263	82	1. 07
0	,064	41	,273	83	1. 10
1	,066	42	,283	84	1. 14
2	,068	43	,294	85	1. 17
3	,071	44	,305	86	1. 21
4	,074	45	,316	87	1. 24
5	,076	46	,328	88	1. 28
6	,079	47	,339	89	1. 32
7	,082	48	,351	90	1. 36
8	,085	49	,363	91	1. 40
9	,087	50	,375	92	1. 44
10	,090	51	,388	93	1. 48
11	,093	52	,401	94	1. 53
12	,096	53	,415	95	1. 58
13	,100	54	,429	96	1. 63
14	,104	55	,443	97	1. 68
15	,108	56	,458	98	1. 74
16	,112	57	,474	99	1. 80
17	,116	58	,490	100	1. 86
18	,120	59	,507	101	1. 92
19	,124	60	,524	102	1. 98
20	,129	61	,542	103	2. 04
21	,134	62	,560	104	2. 11
22	,139	63	,578	105	2. 18
23	,144	64	,597	106	2. 25
24	,150	65	,616	107	2. 32
25	,156	66	,635	108	2. 39
26	,162	67	,655	109	2. 46
27	,168	68	,676	110	2. 53
28	,174	69	,698	111	2. 60
29	,180	70	,721	112	2. 68
30	,186	71	,745	113	2. 76
31	,193	72	,770	114	2. 84
—	—	73	,796	115	2. 92
32	,200	74	,823	116	3. 00
33	,207	75	,851	117	3. 08
34	,214	76	,880	118	3. 16
35	,221	77	,910	119	3. 25

Table continued.

Temperature.	Force of vap in inches of mercury.	Temperature.	Force of vap. in inches of mercury.	Temperature.	Force of vap. in inches of mercury.
120°	3. 33	166°	10. 96	212°	30. 00
121	3. 42	167	11. 25		
122	3. 50	168	11. 54	213	30. 60
123	3. 59	169	11. 83	214	31. 21
124	3. 69	170	12. 13	215	31. 83
125	3. 79	171	12. 43	216	32. 46
126	3. 89	172	12. 73	217	33. 09
127	4. 00	173	13. 02	218	33. 72
128	4. 11	174	13. 32	219	34. 35
129	4. 22	175	13. 62	220	34. 99
130	4. 34	176	13. 92	221	35. 63
131	4. 47	177	14. 22	222	36. 25
132	4. 60	178	14. 52	223	36. 88
133	4. 73	179	14. 83	224	37. 53
134	4. 86	180	15. 15	225	38. 20
135	5. 00	181	15. 50	226	38. 89
136	5. 14	182	15. 86	227	39. 59
137	5. 29	183	16. 23	228	40. 30
138	5. 44	184	16. 61	229	41. 02
139	5. 59	185	17. 00	230	41. 75
140	5. 74	186	17. 40	231	42. 49
141	5. 90	187	17. 80	232	43. 24
142	6. 05	188	18. 20	233	44. 00
143	6. 21	189	18. 60	234	44. 78
144	6. 37	190	19. 00	235	45. 58
145	6. 53	191	19. 42	236	46. 39
146	6. 70	192	19. 86	237	47. 20
147	6. 87	193	20. 32	238	48. 02
148	7. 05	194	20. 77	239	48. 84
149	7. 23	195	21. 22	240	49. 67
150	7. 42	196	21. 68	241	50. 50
151	7. 61	197	22. 13	242	51. 34
152	7. 81	198	22. 69	243	52. 18
153	8. 01	199	23. 16	244	53. 03
154	8. 20	200	23. 64	245	53. 88
155	8. 40	201	24. 12	246	54. 68
156	8. 60	202	24. 61	247	55. 54
157	8. 81	203	25. 10	248	56. 42
158	9. 02	204	25. 61	249	57. 31
159	9. 24	205	26. 13	250	58. 21
160	9. 46	206	26. 66	251	59. 12
161	9. 68	207	27. 20	252	60. 05
162	9. 91	208	27. 74	253	61. 00
163	10. 15	209	28. 29	254	61. 92
164	10. 41	210	28. 84	255	62. 85
165	10. 68	211	29. 41	256	63. 76

Table continued.

Temperature.	Force of vap. in inches of mercury.	Temperature.	Force of vap. in inches of mercury.	Temperature.	Force of vap. in inches of mercury.
257°	64. 82	280°	88. 75	303°	115. 32
258	65. 78	281	89. 87	304	116. 50
259	66. 75	282	90. 99	305	117. 68
260	67. 73	283	92. 11	306	118. 86
261	68. 72	284	93. 23	307	120. 03
262	69. 72	285	94. 35	308	121. 20
263	70. 73	286	95. 48	309	122. 37
264	71. 74	287	96. 64	310	123. 53
265	72 76	288	97. 80	311	124. 69
266	73. 77	289	98. 96	312	125. 85
267	74. 79	290	100. 12	313	127. 00
268	75. 80	291	101. 28	314	128. 15
269	76. 82	292	102. 45	315	129. 29
270	77. 85	293	103. 63	316	130. 43
271	78. 89	294	104. 80	317	131. 57
272	79. 94	295	105. 97	318	132. 72
273	80. 98	296	107. 14	319	133. 86
274	82. 01	297	108. 31	320	135. 00
275	83. 13	298	109. 48	321	136. 14
276	84. 35	299	110. 64	322	137. 28
277	85. 47	300	111. 81	323	138. 42
278	86. 50	301	112. 98	324	139. 56
279	87. 63	302	114. 15	325	140. 70

On Vapour from Ether, &c.

We come now to the consideration of vapour from other liquids. Some liquids are known to be more evaporable than water; as liquid ammonia, ether, spirit of wine, &c. others less; as, quicksilver, sulphuric acid, liquid muriate of lime, solution of potash, &c. and it appears that the force of vapour from each, in a vacuum, is proportionate to its evaporability. M. Bettancourt maintains that the force of vapour from spirit of wine is in a constant ratio to that from water at all temperatures; namely, as 7 to 3 nearly. My first experiments with spirits of wine led me to adopt this conclusion, and naturally suggested that the force of vapour from any other liquid would bear a constant ratio to that of water. The principle, however, is

not true, either with regard to spirit of wine or any other liquid. Experiments made upon six different liquids agree in establishing this as a general law ; namely, *that the variation of the force of vapour from all liquids is the same for the same variation of temperature, reckoning from vapour of any given force:* thus assuming a force equal to thirty inches of mercury as the standard, it being the force of vapour from any liquid boiling in the open air, we find *aqueous* vapour loses half its force by a diminution of 30° of temperature ; so does the vapour of any other liquid lose half its force by diminishing its temperature 30° below that in which it boils ; and the like for any other increment or decrement of heat. This being the case, it becomes unnecessary to give distinct tables of the force of vapour from different liquids, as one and the same table is sufficient for all. But it will be proper to relate the experiments on which this conclusion rests.

Experiment on Sulphuric Ether.

The ether I used, boiled in the open air at 102 degrees. I filled a barometer tube with mercury, moistened by agitation in ether. After a few minutes a portion of ether rose to the top of the mercurial column, and the height of the column became stationary. When the whole had acquired the temperature of the air in the room, 62 , the mercury stood at 17.00 inches, the barometer at the same time being 29.75. Hence the force of vapour from ether at 62° is equal to 12.75 inches of mercury, which accords with the force of aqueous vapour at 172°, temperatures which are 40° from the respective boiling points of the liquids. By subsequent observations I found the forces of the vapour from ether in all the different temperatures from 33° to 102° exactly corresponded with the forces of aqueous vapour of the like range, namely, from 142° to

212°: the vapour from ether depresses the mercury about six inches in the temperature of 32 degrees.

Finding that ether *below* the point of ebullition agreed with water below the said point, I naturally concluded that ether *above* the point would give the same force of vapour as water above it; and in this I was not disappointed; for, upon trial it appeared that what I had inferred only from analogical reasoning respecting the force of aqueous vapour above the boiling point, actually happened with that from ether above the said point. And ether is a much better subject for experiment in this case than water, because it does not require so high a temperature.

I took a barometer tube of 45 inches in length, and having sealed it hermetically at one end, bent it into a syphon shape, making the legs parallel, the one that was close being nine inches long, and the other thirty-six. Then conveyed two or three drops of ether to the end of the closed leg, and filled the rest of the tube with mercury, except about ten inches at the open end. This done, I immersed the whole of the short leg containing the ether into a tall glass containing hot water; the ether thus exposed to a heat above the temperature at which it boils, produced a vapour more powerful than the atmosphere, so as to overcome its pressure and raise a column of mercury besides, of greater or less length according to the temperature of the water. When the water was at 147° the vapour raised a column of 35 inches of mercury, when the atmospheric pressure was 29.75: so that vapour from ether of 147 degrees is equivalent to a pressure of 64.75 inches of mercury; agreeing with the force of aqueous vapour of 257 degrees, according to the preceding estimation: in both cases the temperatures are 45 degrees above the respective points of ebullition. In all the temperatures betwixt 102 degrees and 147 degrees the forces of ethereal vapour corresponded with those of aqueous vapour,

as per table, betwixt 212 degrees and 257 degrees. I could not reasonably doubt of the equality continuing in higher temperatures; but the force increases so fast with the increase of heat, that one cannot extend the experiments much farther without tubes of very inconvenient lengths. Being desirous however to determine the force of the ethereal vapour experimentally up as high as 212°, I contrived to effect it as follows:—Took a syphon tube, such as described above, only not quite so long, and filled it in the manner above mentioned, with ether and mercury, leaving about ten inches at the top of the tube vacant; then having graduated that part into equal portions of capacity, and dried it from ether, I drew out the end of the tube to a capillary bore, cooled it again so as to suffer the internal atmospheric air to be of the proper density, and suddenly sealed the tube hermetically, thus inclosing air of a known force in the graduated portion of the tube. Then, putting that part of the tube containing ether into boiling water, vapour was formed which forced the mercurial column upwards and condensed the confined air, till at length an equilibrium took place. In this way I found 8.25 parts of atmospheric air of the force 29.5 were condensed into 2.00, at the same time a perpendicular column of 16 inches of mercury in addition pressed upon the vapour. Now the force of elastic fluids being inversely as the space, we have 2.00 : 29.5 : : 8.25 : 121.67 inches = the force of the air within; to which adding 16 inches, we obtain 137.67 = the whole force sustained by the vapour, measured in inches of mercury. The force of aqueous vapour, at the same distance beyond the boiling point, or 322°, is equal to 137.28, per table. Thus it appears that in every part of the scale on which experiments have been made, the same law of force is observable with the vapour of ether as of water.

Experiments on Spirit of Wine.

By boiling a small portion of the spirit I used (about one cubic inch) in a phial, the thermometer stood at 179 degrees at the commencement; but by continuing the ebullition it acquired a greater heat. The reason is, the most evaporable part of the spirit flies off during the process of heating, and the rest being a weaker compound, requires a stronger heat. The true point of ebullition, I believe, was nearly 175 degrees. The force of the vapour from this spirit at the temperature of 212 degrees, I found both by an open syphon tube and one hermetically sealed with atmospheric air upon the mercurial column, as with ether, to be equal to 58 and an half inches of mercury. This rather exceeds the force of aqueous vapour at an equal distance from the boiling point; but it is no more than may be attributed to unavoidable little errors in such experiments. In a barometer tube the spirituous vapour at 60 degrees, over the mercury, depresses the column about 1.4 or 1.5 inches; which is something less than the due proportion; one cause of this may be the evaporability of spirits, which in operating on small quantities, quickly dissipates part of their strength." *(Dalton.)*

The principles and manner of operation of the steam-engines of Savery, Newcomen and Cawley, and of Watt, may be understood from the following brief explanations and remarks, which I extract from Hornblower's communication to Gregory. 2 *Nich.* 354.

1. SAVERY'S ENGINE.—Let there be a sucking pipe with a valve opening upwards at the top, communicating with a close vessel of water, not more than thirty-three feet above the level of the reservoir, and the steam of boiling water be thrown on the surface of the water in the vessel, it will force it to a height as much greater than 33 feet as

the elastic force of the steam is greater than that of air; and if the steam be condensed by the injection of cold water, and a vacuum thus formed, the vessel will be filled from the reservoir by the pressure of the atmosphere; and the steam being admitted as before, this water will also be forced up; and so on successively.

Such is the principle of the first steam-engine, said by the English to be invented by the *Marquis of Worcester;* while the French ascribe it to *Papin:* though we believe the fact is that *Brancas*, an Italian, applied the force of steam ejected from a large eolopile as an impelling power for a stamping-engine so early as 1629. The hint so obscurely exhibited in the marquis of Worcester's Century of Inventions, was carried into effect by captain Savery.

2. NEWCOMEN'S.—If the steam be admitted into the bottom of a hollow cylinder, to which a solid piston is adapted, the piston will be forced upwards by the difference between the elastic forces of steam and common air; and the steam being then condensed, the *piston will descend by the pressure of the atmosphere*, and so on successively. This is the principle of the steam-engine first contrived by Messieurs *Newcomen* and *Cawley*, of Dartmouth. This is sometimes called the atmospherical engine, and is commonly a forcing-pump, having its rod fixed to one end of a lever, which is worked by the weight of the atmosphere upon a piston at the other end, a temporary vacuum being made below it by suddenly condensing the steam, that had been admitted into the cylinder in which this piston works, by a jet of cold water thrown into it. A partial vacuum being thus made, the weight of the atmosphere presses down the piston, and raises the other end of the straight lever, together with the water, from the well. Then immediately a hole is uncovered in the bottom of the cylinder, by which a fresh quantity of hot steam rushes in from a boiler of water below it, which

proving a counterbalance for the atmosphere above the piston, the weight of the pump-rods, at the other end of the lever, carries that end down, and raises the piston of the steam-cylinder. The steam hole is then immediately shut, and a cock opened for injecting the cold water into the cylinder of steam, which condenses it to water again, and thus making a vacuum below the piston, the atmosphere again presses it down and raises the pump-rods, as before ; and so on continually.

3. WATT's.—The great features of improvement made by Mr. *Watt* upon the engine of Newcomen and Cawley are, as Mr. Nicholson remarks, first, that the elasticity of the steam itself is used as the active power in this engine;* and secondly, that besides various other judicious arrangements for the economy of heat, he condenses the steam, not in the cylinder, but in a separate vessel.

In the cylinder or syringe, concerning which we have spoken, in mentioning the engine of Newcomen, let us suppose the upper part to be closed, and the piston-rod to slide air tight through a collar of leathers. In this situation, it is evident that the piston might be depressed by throwing the steam upon its upper furface, through an aperture at the superior end of the cylinder. But if we suppose the external air to have access to the lower surface of the piston, we shall find that steam no stronger in its elasticity than to equal the weight of the atmosphere would not move the piston at all ; and consequently that this new engine would require much denser steam, and consume much more fuel than the old engine. The remedy for this evil is to maintain a constant vacuum beneath the piston. If such a vacuum were originally produced by steam, it is certain that its permanency could

* The Piston being forced downward, not by the pressure of the atmosphere, as in Newcomen's, but by the elastic force of Steam thrown on the top of the piston.

not be depended on, unless the engine contained a provision for constantly keeping it up. Mr. Watt's contrivance in his simplest engine is as follows : The steam is conveyed from the boiler to the upper part of the cylinder through a pipe, which also communicates occasionally with the lower part, and beyond that space with a vessel immersed in a trough of water ; in which vessel the condensation is performed by an injected stream of cold water. This water is drawn off, not by an eduction-pipe but by a pump, of which the stroke is sufficiently capacious to leave room for the elastic fluid, separated during the injection, to follow and be carried out with the injection water. Suppose now the piston to be at its greatest elevation, and the communication from the boiler to the upper as well as to the lower parts of the cylinder to be opened. The steam will then pass into the whole internal part of the engine, and will drive the air downwards into the condenser, and thence through the valves of the air-pump. In this situation, if the communication from the boiler to the lower part of the cylinder be stopped, and an injection be made into the condenser, a vacuum will be produced in that vessel, and the steam contained in the lower part of the cylinder and communication pipe will expand itself with wonderful rapidity towards the condenser, so that in a period of time too minute to be appreciated, the whole of the steam beneath the piston will be practically condensed. The steam which continues to act above the piston will immediately depress it into the vacuum beneath ; at the same time that by connection with the external apparatus the piston of the air-pump also descends in its barrel. When the stroke is nearly completed downwards, the requisite part of the apparatus shuts the communication with the boiler, opens that between the upper and lower parts of the cylinder and condensing vessel, and turns the injection-cock. At this ve-

ry instant the piston loses its tendency to descend, because the steam presses equally on both surfaces, and continues its equality of pressure while the condensation is performed. It therefore rises; the injection is stopped; and the air-pump making its stroke, suffers the injection water and a considerable part of the elastic fluid to pass through its lower valve. The vacuum is thus kept up through the whole internal capacity of the engine. As soon as the piston has reached the upper part of the cylinder, the communication to the under part of the cylinder is stopped, and that with the boiler opened, as before; the consequence of which is, that the piston again descends; and in this manner the alternations repeatedly take place.

The principal augmentation of power in this engine, compared with that of Newcomen, arises from the cylinder not being cooled by the injection water, from its being practicable to use steam, which is more powerful than the pressure of the atmosphere, and from the employing of this steam both to elevate and to depress the piston. In general, these engines are worked by steam, which would support a column of four or five inches of mercury besides the pressure of the atmosphere, and sometimes more; for Mr. Nicholson says, he has sometimes seen the gage as high as eight inches. Mr. Watt has made several successive modifications and additions to the engine just described, some of which will be further spoken of in the course of this article.

4. It has been customary, when treating of steam-engines, to present several theorems for the computation of their power and effects. But as all which has hitherto been advanced on these points seems to us very vague and unsatisfactory, we shall not delude the student with an appearance of mathematical accuracy, when it is so far from being attained. It is obvious enough that the absolute power of a steam-engine is in the compound ratio of

the area of the piston, the pressure upon each inch of it, the length of the stroke, and the number of strokes in any assigned time: but the pressure upon any portion of the piston can only be ascertained by experiment and observation, and that with difficulty, because of our uncertain methods of estimating friction and other species of resistance; while judicious observations would with much less labour determine the work actually performed, either when the steam-engine works pumps, or gives motion to any kind of mills. The quantity of water raised by pumps in a given time may soon be estimated: and when the alternating motion of the steam-piston is converted into a rotatory one, the real effect the engine is capable of producing may be ascertained by observing the velocity with which a given weight is raised when suspended from the axle to which the rotation is first given.

The usual method of estimating the effects of engines by what are called "horse powers" must inevitably be very fallacious, unless all engineers could agree as to the quantity of work which they would arbitrarily assign to *one* horse, and in that case the term would manifestly be nugatory. It may also be observed, that in determining the comparative value of different steam-engines, it is not sufficient to compare the quantities of work each will perform in equal times; for the expence of erection, the probability of repairs being more or less frequent on account of the complexness or simplicity of construction, and the quantities of fuel consumed by each, must likewise be taken into the account.*

In giving a clear explanation of the principle of this machine, (Watt's) it will be necessary to deviate from the

* Boulton and Watt have fixed and determined what they mean by a horse-power, viz. a power that will raise 33000lbs. one foot high in a minute, at a medium rate of working the engine.

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precise disposition of the parts as they are usually put together: but in fig. 1. of the plate, this deviation is very little, and represents a single engine. A the cylinder in which the piston moves, B the steam-pipe, D the condenser, E the discharging-pump, F a bottom common to the pump and condenser, in which is an occasional communication by a hanging valve at F: *g* is a valve to be lifted by the engine at every stroke, for the purpose of condensing the steam; *h* is a valve placed outside the cistern (of which *x x x x* is a section on purpose to shew the contents), but communicates only with the condenser by a pipe passing through the side of the cistern, and is inserted at the side of the condenser; *i* is a valve to be lifted by the engine, and opens a communication between the cylinder and the condenser; *k* is a valve to be lifted by the engine, and opens a communication between the lower part of the cylinder and the steam-pipe; and *l* is also a valve of the same kind, opening a passage from the boiler to all parts of the engine.

The piston-rod, which is here broken off at *m*, is connected by a chain to the lever or beam, which is supported on a wall of good masonry, with proper pivot-blocks for support to the gudgeons; and as this kind of engine is usually employed for pumping water, another set of chains at the other end of the beam is appropriated to connect to the pump-rods.

Then to set the engine to work, the first thing is to lift the three valves *i*, *k*, and *l* (for which there are apparatus too minute to lay down on this scale); these being opened, the steam occupies every cavity and crevice of the engine, and in a little while displaces all the air in the cylinder, condenser, &c. which is discharged at the valve *h*: this valve is always covered with water in a small cistern attached to the side of the large one; for it is hardly in the power of art to fit it to that degree of accuracy as to

Boulton & Watts

Single Engine.

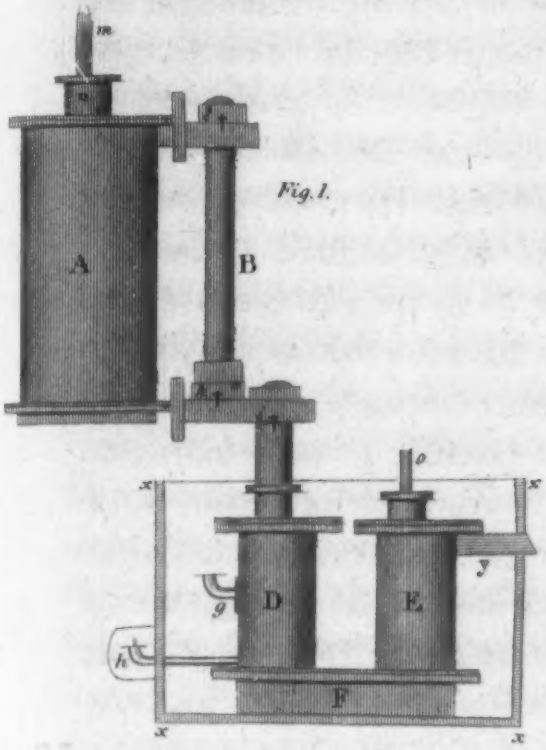
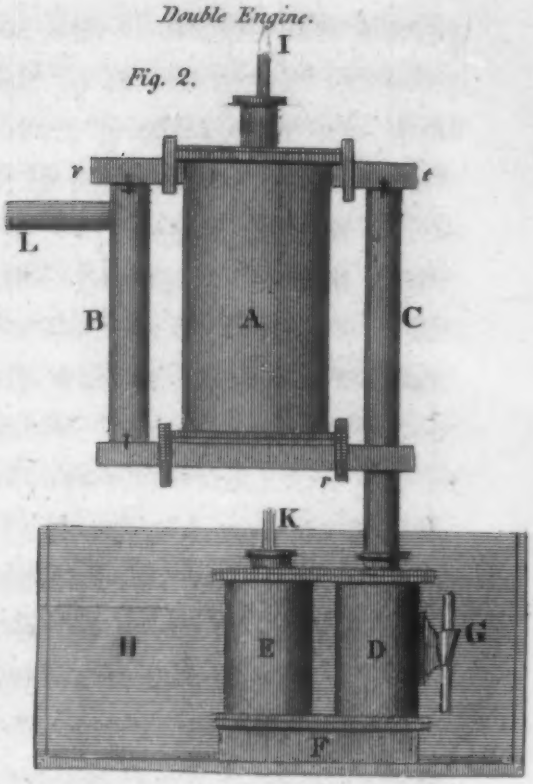


Fig. 1.

Boulton & Watts

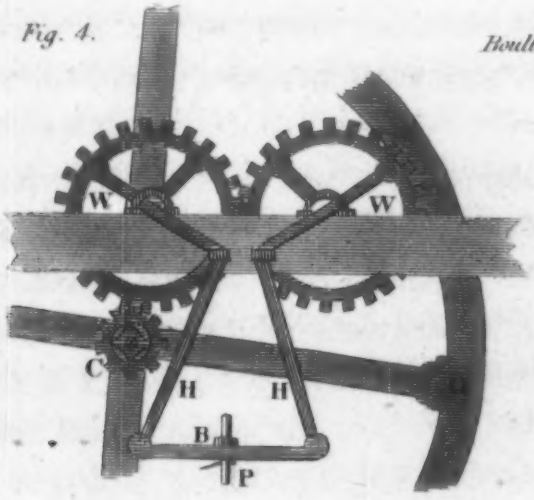
Double Engine.

Fig. 2.



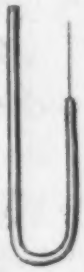
Cartwright's parallel motion.

Fig. 4.



Boulton & Watts Barometer-Gauge.

Fig. 3.



ensure its tightness: but here the air is discharged at first setting the engine to work; and this valve is called the *blowing* valve. When the cylinder and other vessels are properly heated and the air discharged, which is well known by a very smart crackling noise at that valve, like a violent decrepitation of salt in a fire:* these valves *k* and *i* are to be shut; and after waiting a few seconds, gently open the valve *i*: and if the engine does not move, the injection valve *g* must be opened a little;† and if the engine does not move, then the operation of blowing must be performed again, though but for a few seconds, and the engine in general will go off smartly.

In all engines on this principle, it is necessary that the parts appropriated to condensation of the steam, should be kept as cold as possible, and that those parts intended for the operation or passage of the steam be kept as hot as possible: hence the discharging pump and condenser are placed in a cistern of cold water kept constantly full, and a little running away; and if the injection-valve is placed low in this cistern, it will take the water in the coldest state.

As the condenser is immersed in water to be kept cold, so the cylinder should if possible be immersed in steam to be kept hot: for which purpose Mr. Watt formerly used a casing round the cylinder, and at the top and bottom; and this would have been attended with very beneficial effects if it did not enlarge the steam surface, and expose it to a more rapid condensation when it ought to

* This noise is occasioned by the air being all gone, and the water producing a sudden and rapid condensation of the steam.

† The valve *i* being opened, there is a passage made from the cylinder to the condenser; but on account of long blowing, the sides of the condenser become hot, and the water in the cistern hot likewise: so that the condensation must needs be very slow, even at the first injection of the water into the condenser.

be preserved; for to have the vacuum as perfect as possible, it is necessary that the cylinder be kept up to such a temperature as to prevent the least condensation on the internal surface either above or below the piston: because, if the sides of the cylinder were to be wet, as in the common atmospherical engine, the vacuum would be vitiated, as it is there occasioned by this wetness or moisture gradually forming to steam, which the outside casing prevents, being filled with steam from the boiler. But if it were possible to cover this outward case with any sort of substance which would entirely prevent the transmission of heat *for that casing*, it would supercede the use of the casing altogether, and would apply with more advantage to the cylinder itself. But we do not know of any substance which will not admit this transmission more or less. They who wish for information on this subject may find it in eount Rumford's Essays.

The first circumstance of importance to the proportion and disposition of the several parts, is the solidity of the vessels and the perfection of the joints. Copper tubes are apt to be unsound at the seams, and other parts which are required to be bent out of a right line; and iron castings, which require any particular sort of stay in the moulding to keep the core from the outside, as these stays are made mostly of wrought iron, they contract more in cooling than the cast-iron does about them, even so as to become loose sometimes; in such cases, it is unutterably perplexing to find out the places or cause of this defection; the joints are suspected for the most part, but even remaking them sometimes proves no amendment; and this must be the cause in general why one engine from the same patterns is better or worse than others. And we have reason to fear that this matter of complaint is on the increase; for self-interest has so powerful a preponderancy, especially in the metropolis, that

we shall despair of having these objects regarded as they were formerly; semblance being for the greatest part the order of the day.

Mr. Watt has adopted a gage (very improperly* called a barometer,) to indicate the degree of vacuum in his engines; and we deem it of important consequence to the well-going of the engine, the profit of the proprietor, and the credit of the engineer; yet in many engines in London we see this important instrument either out of repair, or wholly laid aside. The form is given at fig. 3. They have been made of glass; but if the quicksilver is not very pure, the alloy with which the venders of this article adulterate it is by constant action brought to the surface, and that and the vapour together make the tube so foul that no precision can be obtained. Iron therefore is the best material: both parts of the tube should be correctly of one diameter, or else the result will be erroneous. This tube must communicate with the condenser by a small copper pipe, and a stop-cock be placed between the gage and condenser. The index in this instrument is a light deal rod, which is put into the shorter tube; and quicksilver being poured into it within three inches of the end, the rod is put into the tube, and it floats on the quicksilver. It is almost needless to remark, that the graduations on this instrument must be inverted with regard to those of a single tube.

Perhaps it should have been noticed before, that the rod of the discharging pump is connected with the lever at some point determinable by the length of the stroke; and in this figure it rises with the piston, and brings up the air and water with it, both of which are discharged at the branch *p*, in which is a hanging valve opening outward.

The valve *l*, the office of which is to open or shut the communication between the cylinder and the boiler, is so

* I do not see why. T. C.

particularly connected with the working gear, that by altering the place of a pin it is shut sooner or later, as occasion requires; and when the piston has proceeded half way down, if this valve is shut at that instant, the piston is carried through the remainder of the stroke, partly by the momentum it has already acquired, and partly by the remaining expansion of the steam, which notwithstanding its growing rarer and rarer, is sufficient with its momentum to complete the stroke.

We have observed, that in order to give action to the engine at its first onset, and indeed at every succeeding stroke, the valve *i* is to be lifted. This valve is kept down by a weight equal to the pressure of the atmosphere, added to the elasticity of the steam above that pressure; there being a vacuum beneath it, and the action of the steam upon it. Hence, in large engines it requires a great force to lift it up.

WATT's *double Engine.** We have represented the mode of working this engine at fig. 2. where we must deviate largely from the practical application, in order to give a comprehensive explanation. A is the cylinder, as in the single engine; B is a pipe appropriated to deliver the steam from the boiler through the branch L; from thence it enters the cylinder alternately by the valves *v*, *w*, both opening towards the steam side. The pipe C has also two valves, one at the upper end of the pipe in the box *t*, and one which we must designate at the joint *r*, both opening toward the cylinder. The condenser D has a blowing-valve, like the former figure in the single engine; but the injection is made by a cock G, which has a pipe reaching near the bottom of the cistern; and when the engine is at work this cock is always open, and the injection always running in, because the steam is constantly

* Which Hornblower derides. T. C.

coming from the cylinder either above or below the piston, and its operation is as follows:

When the air is blown out of the engine, and the piston happens to be in its upper situation, the valve *v* on the steam side is lifted, and the valve *r* on the exhausting side is opened: the exhausting-valve *r* takes the steam from below the piston, while the steam by the valve *v* enters on the upper surface, and a stroke is made; and at the instant the piston comes to its place at the bottom of the cylinder, these valves are both shut, and the valves *w* and *t* are opened, and the upward stroke commences, and so on alternately.

It must be observed here that, whereas the piston in the single engine is pendant on the lever by the chains lying in the arch of the inner end, this must be connected by a mode that shall render the rod rigid in its action upward; for which purpose there is a system of transverse joints which compel the rod to a motion parallel to itself. At the other end of the beam or lever is a rod which connects the motion of the engine to a fly; and Mr. Watt has chosen to do this by a very ingenious application of one wheel fixed on the axis of the fly, and another fixed on the rod that is connected to the lever, by which means the fly makes one entire revolution, while the engine makes but one stroke; and thus the fly makes as many revolutions as the engine does strokes; but we are inclined to give the preference to a simple crank with a fly of such weight as shall have the desired momentum with less velocity, simplicity being ever a desideratum in the construction of machinery.

Cartwright's Engine. A steam engine has been invented by Mr. Edmund Cartwright, which has as much merit as can possibly be attributed to a gentleman engaged in the pursuit of mechanical studies for his own amusement. Mr. Cartwright has two very important desiderata

in view, a tight piston and a vacuous condenser; that is to say, a condenser from which the atmospheric air is excluded: to accomplish which it is made of as thin copper as it will admit, exposing a large surface to the water, then the steam internally comes in contact with the metal of the same temperature, and hence the condensation. We wish it were possible to put this grand design into a decided effect: but from some particulars we have observed in the doctrine of condensation, no method yet explored will obtain so rapid a condensation as actual contact with the water: we do not account for this by any chemical affinity, but by the exposure of surface; for the experiment has been tried to our satisfaction, that when the jet was not in a dispersive state, the condensation was tardy and inactive; and if it were possible to disperse the jet into a mist, we should obtain the most prompt condensation possible.

But still we do not conceive an instantaneous condensation is absolutely necessary; for if it is performed during the time of the required stroke, that is all which is wanted. We cannot say whether Mr. Cartwright has succeeded ultimately to this point or not.

We remember to have seen preparations for an apparatus for this mode of condensing some years since, by an assemblage of taper pipes of about a quarter of an inch diameter, exposing a surface of between 90 and 100 feet to a 20-inch cylinder; but an accident from a rude hand prevented its application for that time, and we do not think it was ever resumed.

The packing of Mr. Cartwright's piston is composed of a series of segments of brass, the arches of which conform exactly to the circumference of the cylinder; these are to be laid on the verge of the piston so as to make one entire disk, then another and another stratum super stratum until the designed thickness is acquired:

then to keep these segments in constant tendency to the place of action, there are a set of springs very nicely contrived to act on the concave edge, which, no doubt, will keep them to their work; but the difficulty is how to preserve the fit at the junctures: it is impossible for the segment of a small circle to become the segment of a larger circle*. But we do not suppose Mr. Cartwright to have intended this metallic packing to compensate the irregular figure of the steam-vessel, for it is impossible; beside, Mr. Cartwright's notions of accuracy would never suffer him to admit a steam-vessel to his engine which was not a perfect cylinder; in which case these segments may have but little wear, though, if they were of metal in any degree softer than the cylinder, the dust which will find its way there, would wear away the cylinder so as to be sensibly detrimental: added, that this packing could never apply to a double engine. It, however, serves as a very elegant specimen of the inventor's inclination to accurate working.

Since the above was written, we have seen an engine of Mr. Cartwright's at a tan-yard near Horsley-Down,† which gives great satisfaction to the proprietor. The piston, by the account of the tender of the engine, has not even been looked at for many months, nor has he any indications that it will be necessary for many more. This account receives strong confirmation by the appearance of the quantity of condensed steam which is discharged from the engine every stroke, which, as it is not effected in the common way (by injection), can be very exactly est mated.

* Admitting that these segments wear away on the outer arches, the inner arches must recede from the centre, and therefore will be one continued deduction from the entire circle.

† Near London.

Its construction is very simple, and it performs its operations very smoothly and effectually.*

The preceding is a tolerably correct though brief account of Savary's, Newcomen's, Watt's and Cartwright's engines: but it will in my opinion be of use to state under various modes of expression the same general facts, that the distinctive characters, and the successive improvements of the principal steam engines may become familiar to the reader. The subject is new in this country, and is extremely important. I have already given all the preliminary knowledge relating to the power of steam that bears upon the question; and I mean in the course of this and the next number to give all the knowledge necessary to a full understanding of the theory of the Steam Engine. The following brief history I extract from Professor Playfair's angry review of Gregory and Hornblower's account of Steam engines; but as I have nothing to do with the illiberal remarks of the latter, or the tart replies of the Professor, I insert no more than relates to the history of Mr. Watt's discoveries and improvements. Edinb. Rev. for Jan. 1809.

"The first idea of the steam-engine is found in the writings of that celebrated projector, the Marquis of Worcester, who, in the year 1663, published a small tract, entitled, "A Century of Inventions," consisting of short

* Mr. Cartwright's contrivance for preserving the parallel motion of the piston-rod, at the same time that it communicates the rotatory motion to the fly, is very ingenious, and is therefore shewn in the plate fig. 3. where P is the top of the piston-rod, upon which is screwed a transverse bar B: to the ends of this bar, at equal distances from the top of the piston-rod, are attached the two equal connecting rods H, H, which as the piston rises and falls turn the cranks and the two equal wheels W, W; these two equal wheels work into each other, and one of them drives the pinion C upon the same axis as the fly-wheel O; thus communicating the rotatory motion to the other parts of the machinery. (Hitherto from Hornblower's account. T. C.

heads or notices of schemes, many of them obviously impracticable, which at various times had suggested themselves to his very fertile and warm imagination. No contemporary record exists to illustrate or verify his description of the contrivance which we presume to call a steam-engine, or to inform us where, and in what manner, it was carried into effect; though it is evident, from his account, that he had actually constructed and worked a machine that raised water by steam. His description of the method is short and obscure; but inclines us to think, contrary to what many have supposed, that the force of his engine was derived solely from the *elasticity* of steam; and that the *condensation* of steam by cold, was no part of his contrivance. This last, we believe, was the invention of Captain Savary, who, in 1696, published an account of his machine, in a small tract entitled the *Miner's Friend*, having erected several engines previous to that period. In these engines the alternate condensation and pressure of the steam took place in the same vessel into which the water was first raised, from a lower reservoir, by the pressure of the atmosphere, and then expelled into a higher one, by the elastic force of strong steam.

Steam, it must be observed, was thus employed merely to produce a vacuum, and to supply the strength that was applied, for a like effect, to the sucker or piston of an ordinary pump; and it was a great step to have discovered a method of bringing the air to act in this manner by the application of heat to water, without the assistance of mechanical force.

The next essential improvement was made by Newcomen, for which he obtained a patent in 1705. It consisted in separating the parts of the engine in which the steam was to act, from those in which the water was to be raised; the weight of the atmosphere being employed only for the purpose of pressure, and the steam for that

of first displacing the air, and then forming a vacuum by condensation. Newcomen was thus enabled to dispense with the use of steam of great and dangerous elasticity, to work with moderate heats, and to remove at least some part of the causes of wasteful and ineffectual condensation. To him we are indebted for the introduction of the steam cylinder and piston, and for their connection with the pump by means of the main lever with its rods and chains, to which we might add several other subordinate contrivances, which do great credit to his ingenuity.

Still, however, the machine required the constant attendance of a man to open and shut the cocks at the proper intervals, for the alternate admission of steam and cold water: and although traditional report attributes the invention of the mechanism by which the engine was made to perform this work itself, to the ingenuity of an idle boy, we know that the contrivance was first perfected by Mr. Henry Beighton, in 1717, who also improved the construction of several other parts of the engine. From this time to the year 1764, there seems to have been no material improvement in the structure of the engine, which still continued to be known by the appellation of Newcomen's, or the atmospheric engine. The boilers, however, had been removed from under the cylinder in some of the larger engines, and the cylinder had been fixed down to a solid basis. Still the steam was condensed *in* the cylinder; the hot water was expelled by the steam; the piston was pressed down by the weight of the atmosphere, and kept tight by being covered with water. It was moreover considered as necessary that the injection cistern should be placed on high, in order that the water might enter with great force. It had been found by experience, that the engine could not be loaded with advantage, with more than seven pounds on each

square inch of the piston; and the inferiority of that power to the known pressure of the atmosphere, was, without due consideration, imputed wholly to friction. The bulk of water when converted into steam was very erroneously computed; the quantity of fuel necessary to evaporate a given quantity of water was not even guessed at; whether the heat of steam is accurately measured by its temperature was unknown; and no good experiment had been made to determine the quantity of injection water necessary for a cylinder of given dimensions. In a word, no man of science in this country had considered the subject since Desaguliers; and his writings, in many respects, tended more to mislead than instruct.

Such was the state of matters, when, fortunately for science and for the arts, Mr. Watt, then a mathematical instrument-maker at Glasgow, undertook the repair of the model of a steam engine belonging to the university. In the course of his trials with it, he found the quantity of fuel and injection water it required much greater in proportion than they were said to be in large engines; and it soon occurred to him, that this must be owing to the cylinder of this small model exposing a greater surface, in proportion to its contents, than larger cylinders did. This he endeavoured to remedy, by making his cylinders and pistons of substances which conducted heat slowly. He employed wood, prepared on purpose, and resorted to other expedients, without producing the desired effect in any remarkable degree. He found, also, that all attempts to produce a greater degree of exhaustion, or a more perfect vacuum, occasioned a disproportionate expenditure of steam. In reflecting upon the causes of these phenomena, the recent discovery, that water boiled in an exhausted receiver at low degrees of heat, (certainly not exceeding 100 degrees of Fahrenheit, but probably, when the vacuum was perfect, much lower) occurred to him;

and he immediately concluded, that, to obtain any considerable degree of exhaustion, the cylinder and its contents must be cooled down to 100 degrees at least; in which case, the reproduction of steam in the same cylinder must be accompanied with a great expense of heat, and consequently of fuel. He next endeavoured to ascertain the temperature at which water boils when placed under various pressures; and, not having any apparatus at hand by which he could make his experiments under pressures less than that of the atmosphere, he began with trying the temperature of water boiling under greater pressures; and by laying down a curve, of which the *abscissæ* represented the temperatures, and the *ordinates* the pressures, he found the law by which the two are connected, whether the pressure be increased or diminished.

Observing, also, that there was a great error in Desaguliers' calculation of the bulk of water when converted into steam, and that the experiment on which he founded his conclusion was in itself fallacious, he thought it essential to determine this point with more accuracy. By a very simple experiment with a Florence flask, which our limits will not allow us to detail, he ascertained, that water, when converted into steam under the ordinary pressure of the atmosphere, occupies about eighteen hundred times its original space.

These points being determined, he constructed a boiler in such a manner, as to show by inspection, with tolerable accuracy, the quantity of water evaporated in any given time; and he also ascertained by experiment the quantity of coals necessary to evaporate a given quantity of water.

He now applied his boiler to the working model above mentioned; when it appeared that the quantity of steam expended at every stroke, exceeded many times what was sufficient to fill the cylinder; and deducing from

thence the quantity of water required to form as much steam as would supply each stroke of the engine, he proceeded to examine how much cold water was used for injection, and what heat it gained; which, to his very great surprise, he found to be many times the number of degrees which could have been communicated to it by a quantity of boiling water equal to that of which the steam was composed. Suspecting, however, that there might be some fallacy in these deductions, he made a direct experiment to ascertain the degree of heat communicated by steam to water; when it clearly appeared, that one part of water, in the form of steam, at 212 degrees, had communicated about 140 degrees of heat to six parts of water. The fact, thus confirmed, was so contrary to all his previous conceptions, that he at first saw no means of explaining it. Dr. Black indeed had, some time before, made his discovery of latent heat; but Mr. Watt's mind being otherwise engaged, he had not attended sufficiently to it, to make himself much acquainted with the doctrine: but upon communicating his observations to the doctor, he received from him a full explanation of his theory; and this induced him to make further experiments, by which he ascertained the latent heat of steam to be above 900 degrees.

The causes of the defects of Newcomen's engines were now evident. It appeared that the steam could not be condensed so as to form an approximation to a vacuum, unless the cylinder, and the water it contained, were cooled down to less than 100 degrees; and that, at greater degrees of heat, the water in the cylinder must produce steam, which would in part resist the pressure of the atmosphere. On the other hand, when greater degrees of exhaustion were attempted, the quantities of injection water required to be increased in a very great ratio; and

this was followed by a proportionate destruction of steam on refilling the cylinder.

Mr. Watt now perceived, that to make an engine in which the destruction of steam should be the least possible, and the vacuum the most perfect, it was necessary that the cylinder should condense no steam on filling it, and that, when condensed, the water, forming the steam, should be cooled down to 100 degrees, or lower. In reflecting on this desideratum, he was not long in finding that the cylinder must be preserved always as hot as the steam that enters it; and that, by opening a communication between this hot cylinder when filled with steam, and another vessel exhausted of air, the steam, being an elastic fluid, would rush into it, until an equilibrium was established between the two vessels; and that if cold water, in sufficient quantity, were injected into the second vessel, the steam it contained would be reduced to water, and no more steam would enter until the whole was condensed.

But a difficulty arose—How was this condensed steam and water to be got out of the second vessel without letting in air? Two methods presented themselves. One was, to join to this second vessel (which, after him, we shall call *the condenser*) a pipe, which should extend downwards more than 34 feet perpendicular, so that the column of water contained in it, exceeding the weight of the atmosphere, would run out by its own gravity, and leave the condenser in a state of exhaustion, except in so far as the air, which might enter with the steam and injection water, should tend to render the exhaustion less perfect: this air he proposed to extract by means of a pump. The second method which occurred, was to extract both air and water by means of a pump, or pumps; which would possess the advantage over the other, of being applicable in all situations. This latter contrivance was

therefore preferred; and is known by the common name of the Air-pump. There still remained some defects unremedied in Newcomen's cylinder. The piston in that engine was kept tight by water; much of which passing by the sides, injured the vacuum below, by its evaporation; and this water, as well as the atmosphere which came into contact with the upper part of the piston and sides of the cylinder at every stroke, tended materially to cool that vessel. Mr. Watt removed these defects, by applying oils, wax, and fat of animals, to lubricate his piston and keep it tight: he put a cover on his cylinder (with a hole in it made air and steam tight, for the piston rod to pass through,) and employed the elastic force of steam to press upon the piston: he also surrounded the cylinder with a case containing steam, or a case of wood, or of other non-conducting substance, which should keep it always of an equable temperature.

The improvement of Newcomen's engine, so far as the saving of steam and fuel was concerned, was now complete in Mr. Watt's mind; and in the course of the following year, 1765, he executed a working model, the effect of which he found fully to answer his expectations. It worked readily with ten and an half lib. on the inch, and was even capable of raising fourteen lib.; and did not require more than one third of the steam, used in the common atmospheric engine, to produce the same effect. Indeed, the principle of keeping the vessel, in which the elasticity of the steam is exerted always hot, and that in which the condensation is performed always cold, is in itself perfect. For the steam never coming in contact with any substance colder than itself until it had done its office, no part is condensed until the whole effect has been obtained in the cylinder; and when it has acted there, it is so condensed in the separate vessel that no resistance remains: accordingly, the barometer proves a vacuum,

nearly as perfect as by the exhaustion of the air-pump. The whole of the steam and heat is usefully employed; and the contrivance appears scarcely to admit of improvement.

Such is the history of this valuable invention, which we have extracted from Dr. Black and Professor Robison's testimonials, who were privy to Mr. Watt's discovery; as well as from some early letters of his own to confidential friends, to which we have had access.

We have entered thus minutely into the subject, from a desire to do that justice which is due to Mr. Watt, by showing that this great improvement was not the effect of accident, or of casual observation, but the result of deep reflection, of great ingenuity, and much philosophical investigation.

It did not, at the early period we have been speaking of, escape him, that great benefit might be derived from the direct application of the power of steam to driving mills, instead of using it to raise water to act on a wheel, as had heretofore been done; and with this view, he invented and executed the model of a steam wheel, for giving a circular motion to an axis.

His occupations in the business of a civil engineer which he had now taken up, perhaps also the indifferent state of his health, his want of funds, and his apprehension of the prejudices and opposition he might have to encounter, prevented his applying for a patent for the invention we have described, until the year 1769. He had, we believe, previous to, or about that time, erected an engine for his friend Dr. Roebuck of Kinneil, near Borrowstounness, which, upon a large scale confirmed his expectations; the proportionate saving of fuel being from two thirds to three fourths of that of engines on Newcomen's construction. Dr. Roebuck, whose spirit for enterprise and improvement in the arts is well known, foresaw all the advantages likely to result from this invention, and be-

came associated in the prospects which it opened. But some of his own projects having failed, he soon after disposed of his interest to Mr. Boulton, the celebrated founder of Soho manufactory, with whose aid Mr. Watt, in 1 74, solicited and obtained an act of parliament for the extension of the term of his patent for twenty-five years; and the business of making steam engines was soon after commenced by the firm of Boulton and Watt.

In executing his invention on a large scale, Mr. Watt felt the necessity of improving the construction of several of the parts of Newcomen's engine. With this view, he induced Mr. Wilkinson to erect an apparatus for boring the cylinders with more precision than had hitherto been done; he adopted a new mode of constructing the piston and screwing down the packing, and secured the rod in the piston in a more perfect manner; he introduced puppet valves into the steam boxes or nozles, instead of the old sliding regulators; he used better means of opening these valves, and added various improvements in the working gear; he suspended the working beam, so that the centre of motion was below the centre of gravity, instead of being above it, as in the old engines; and he improved the mode of setting the boilers on the grates, as well as the apparatus for keeping the boilers regularly supplied with water.

He introduced also into some of his earliest reciprocating engines, the principle of using the steam to act expansively, which he had discovered so early as the year 1769.*

* This appears by a letter from him to his friend the late Dr. Small, of Birmingham, dated Glasgow, 28th May, 1769; of which the following is an extract.

'I mentioned to you a method of still doubling the effect of 'the steam, and that tolerably easy, by using the power of steam 'rushing into a vacuum, at present lost. This would do little more

The character of his engines being now fully established by the erection of several large ones in Cornwall, and other parts of the kingdom, Mr. Watt recurred to his favourite idea of applying the power of steam to produce motions round an axis.

He had, upon trial, found practical objections to the steam wheel described in his patent; and a second one which he had contrived was also given up; for, upon very full consideration of the subject, it appeared to him, that the object would be better attained by deriving the rotative motion from the rectilinear motion of the piston in the reciprocating engine.

Something of this kind had been attempted by others. An atmospheric engine had been employed at Hartley coalery, in Northumberland, as early as 1768, to draw coals out of a pit. It had a toothed sector on the end of the working beam, working into a trundle, which, by means of two pinions with ratchet wheels, produced a rotative motion, in the same direction, by both the ascending and descending stroke of the arch; and, by shifting the ratchets, the motion could be reversed at pleasure. This engine had no fly-wheel, and went sluggishly and irregularly. Who the inventor was, we do not know.

A patent was taken out in 1769, by a gentleman of the name of Stewart, for an engine which produced a rotative

'than double the effect, but it would too much enlarge the vessels 'to use it all. It is peculiarly applicable to wheel engines, and 'may supply the want of a condenser where force of steam only is 'used: for, open one of the steam valves, and admit steam until 'one fourth of the distance between it and the next valve is filled 'with steam; shut the valve, and the steam will continue to ex-'pand, and to press round the wheel with a diminishing power, 'ending in one fourth of its first exertion. The sum of the series 'you will find greater than one half, though only one fourth steam 'was used. The power will indeed be unequal; but this can be 'remedied *by a fly*, or several other ways.'

motion, by a chain going round a pully, and also round two barrels furnished with ratchet wheels, with a weight suspended to the free end of the chain, which served to continue the motion during the return of the engine. In 1778, Mr. Matthew Washbrough also obtained a patent for communicating a rotative motion from the steam engine, by a method which was virtually the same as that at Hartley; only, he had added a fly-wheel, which we believe was then for the first time employed in the steam engine, though it is evident, from the letter we have quoted from Mr. Watt to Dr. Small, that the former had conceived the idea long previous to this period. Two or three of these engines were erected; but, owing to the defective mode of communicating the motion, were subject to such irregularities and accidents, as rendered them of little use.

The idea of communicating motion from the beam of the steam engine to a crank, in the same manner as is done in the common foot-lathe, had, as we are informed, early occurred to Mr. Watt; but we believe he did not seriously set about reducing his ideas to practice until the year 1778 or 1779. In the first model he then made, in order to equalize the power, two cylinders, acting upon two cranks were fixed upon the same axis, at an angle of 120 degrees from each other; and a weight was placed upon the circumference of the fly-wheel, at an angle of 120° from each of the cranks; which weight was to be so adjusted, as to act when neither of the cranks could do so, and consequently to render the power nearly equal. This model performed to satisfaction; but Mr. Watt having neglected to take out a patent immediately, the essential part of the contrivance was communicated, as we understand, by a workman employed to make the model, to the persons engaged about one of Washbrough's engines; and a patent was taken out for the application of the crank

by the engineer there employed. This did not dishearten Mr. Watt; and, without troubling himself with setting aside a patent which, so long as it continued attached to the common atmospheric engine, could do him little harm, he set about other modes of effecting the same thing; and, in 1781, took out a patent for several new methods of applying the vibrating or reciprocating motion of steam engines to produce a continued rotative motion round an axis; one of which was that beautiful contrivance of the revolving motion of one wheel round another. These and the crank were indifferently used in his engines, without any molestation on the part of the piratical patentee.

This, however, was only a part of what Mr. Watt saw to be necessary, in order to perfect this application of the steam engine. The steam had hitherto been used only to press down the piston, which was returned by a weight at the opposite end of the beam, so that the power of the steam may be said to have been inactive during that period. Mr. Watt remedied this, by applying the power of the steam to press the piston down, as well as to press it up, thus forming alternately a vacuum above and below the piston. This he called *the double engine;* and, in fact, it doubled the power exerted within the same cylinder. He had long had in his mind the idea of this improvement; and had even produced a drawing of it to the house of commons in 1774, at the time he procured the act to prolong his original patent; but the first he executed was, we believe, at Soho in the year 1781 or 1782, and the first public exhibition of it at the Albion Mills a few years later.

About the same period, finding double chains or racks and sectors very inconvenient for communicating the motion of the piston rod to the angular motion of the beam, he invented and applied what has been called the *parallel*

motion, one of the most ingenious and most perfect contrivances in mechanics.

To prevent irregularities in the speed of the engine, arising from variations in the quantum of power used at different intervals in the works to which it was applied, he made an application of the centrifugal force of what is called the *governor*, (before used in the wind and water mills) to regulate the admission of the steam; by this means keeping the engine always at an uniform velocity, and diminishing the consumption of steam in proportion to the power exerted; thus giving the finishing stroke to the perfection of the motion of this machine, and rendering its regularity nearly correspondent with that of the pendulum of a clock.

These inventions are detailed amongst many other contrivances, both relative to steam engines, and the applications of their power in two patents, dated 1782 and 1784. Some of these are highly ingenious: a few may have been first ideas, not yet reduced to practice; and others were no doubt inserted for the purpose of guarding against evasion.

Such is the general outline of the improvements introduced by Mr. Watt into the steam engine; but it would lead us too far, to go into the detail of the applications of this power, or to enumerate the advantages which the country has derived from it. We shall content ourselves with observing, that by means of it, many of the principal mines in the kingdom have been kept open, and rendered productive, when otherwise they must have ceased to work. By the construction of the rotative engine, a new era has been introduced into the manufactures of the kingdom; and it has been in a great measure owing to it, that those manufactures have been carried to an extent unprecedented in the history of nations. The merit and success of these improvements, however, created (as

er of horses, to state the number of the latter to which the new power, under given conditions, would be equivalent; and it is probable that Boulton and Watt felt that such a mode of comparison would be more intelligible to common apprehensions, than a more accurate and scientific formula. It gave the power of an engine expressed in numbers, of which the ordinary strength of a horse is the unit. This, no doubt, is not in itself very exact, the unit being large, and subject to some variation. Relatively to the purpose for which it was used, it was however sufficiently correct; and on this, as on many similar occasions, a more minute measurement would have been less useful. If a historian would express the interval of time between two different events, he is in general satisfied with counting the number of years; and it would be a useless affectation of accuracy to reckon up the months, days, hours and minutes, that must be added or taken away, in order to measure the aforesaid interval with mathematical exactness. So, also, if a man were to ride post from London to York, it would serve his purpose as well to know the distance of these cities in miles, as in feet, inches, and decimals of an inch.

Boulton and Watt, however, have not left the matter in a state that can be accounted incorrect in any case, but have given to it all the accuracy that can be required, when, from the result of experiments made with the strong horses employed by the brewers in London, they have assumed, as the standard of a horses's power, a force able to raise thirty-three thousand lb. one foot high in a minute; and this, no doubt, was meant to include an allowance of power sufficiently ample to cover the usual variations of the strength of horses, and of other circumstances that may affect the accuracy of the result. This determination, we think, could not be unknown to Mr. Gregory, and certainly not to his coadjutor. If, in forming the esti-

success and merit will always do) an host of imitators and detractors, from whom Messrs. Boulton and Watt, during the greater part of the term of their exclusive privilege, experienced the most harassing and obstinate opposition.

Having given this short history of Mr. Watt's improvements we shall proceed to consider the view that Mr. Gregory and his associate have taken of the same subject. These gentlemen have both animadverted with great severity, and we think, with very little reason, on the mode adopted by Boulton and Watt for describing the force of the steam engine by a comparison with the power of horses. 'What is called,' say they, 'the horses' power, is 'of so fluctuating and indefinite a nature, that it is perfect-'ly ridiculous to assume it as a common measure by 'which the force of steam engines and other machines 'should be appreciated.' II. pp. 78. 357.

Now, we are ready to admit, that if nothing more definite were said of any engine than that it did the work of a certain number of horses, this would not convey an idea of its power sufficiently accurate for many of the purposes of science. It might, however, be accurate enough for many of the purposes of common life. Now, if the thing wanted was an approximate and popular standard of comparison, such as might be intelligible to every body, and sufficiently exact for ordinary purposes, it is certain, that a more convenient expression could not easily be found than that which is here referred to. Prior to Mr. Watt's application of the steam engine to produce rotative motion, the great manufactories of the kingdom had their millwork set in motion by the agency of water, of wind, or of horses; and the latter had, for many years, been almost exclusively employed in the breweries and distilleries of the metropolis. It was therefore natural for one who wished to substitute the power of steam for the pow-

mate just mentioned, the power of a horse is rated, as we think it is, above the ordinary average, this circumstance cannot be complained of by the public, as it tends to represent the advantage of the engines less than it will be found in real practice."

The following *account of* STEAM ENGINES, from Gregory's Encyclopedia, being connected with the last plate of this number, I give it, though at the expence of some repetition. T. C.

ENGINE, *steam.* The steam-engine is one of the noblest monuments of human ingenuity. It was originally invented by the marquis of Worcester, in the reign of Charles II. This nobleman, who appears to have been possessed of much knowledge, with a fertile imagination, published in 1663, a small book, called "A Century of Inventions," giving an account of a hundred discoveries or contrivances of his own; but the descriptions of many of them are altogether unintelligible.

Among them is an account of his invention of raising water by the force of steam, which, now that we are possessed of the engine, appears to agree very well with its construction. But as there is no plate to accompany his description, we are entirely unacquainted with the particular mode in which he applied the power of steam. It does not appear, however, that he met with sufficient encouragement; and this useful discovery was long neglected.

Towards the end of the century, captain Savary, a person of great ingenuity, having probably seen the account of the marquis of Worcester's invention, was convinced of its practicability, and succeeded in constructing a machine of this kind. He obtained a patent for the invention, and erected several steam-engines, which he described in a book entitled "The Miner's Friend," published in 1696.

The following is the description of his machine, as improved by himself:

A (Plate fig. 1) is a strong boiler, built in a furnace for generating steam. From the top of this boiler there proceeds a pipe, b, which conveys the steam into another strong vessel, r, called the receiver. This pipe has a cock at c, called the steam-cock. In the bottom of the receiver is a pipe S, which communicates with the rising-pipe H n k, the lower end of which is immersed in the well from which the water is to be raised. Immediately below the place where the pipe S enters the rising-pipe, there is a valve, n, opening upwards. A similar valve is also placed at i, above the pipe S. Lastly, there is a pipe e, which branching off from the rising-pipe, enters the top of the receiver. This pipe has also a cock, d, called the injection-cock. The mouth of the pipe e, has on the end f a nozzle, pierced full of holes, pointing from a centre in every direction. The keys of the two cocks c and d, are united by the handle h, called the regulator.

The mode of operation is as follows: Let the regulator be so placed, that the steam-cock c be open, and the injection-cock d shut: put water into the boiler A, and make it boil. The steam from it will enter the pipe b, and fill the receiver, first driving out the air which it before contained; a considerable quantity of steam will be at first condensed by the cold sides of the receiver; but it being at length warmed, the steam will proceed into the rising-pipe, lifting up the valve i. When this is perceived to be the case, by the rising-pipe feeling warm, and hearing the valve i rattle, the communication is now to be cut from the boiler, by shutting the steam-cock c, the injection cock d being also shut. The receiver now gradually cools, and the steam included in it condenses into water. When this is the case, as the air was at first driven out by the steam, and cannot return again, all the cocks being shut,

ENGINES.

Watts's Engine

Fig. 3.

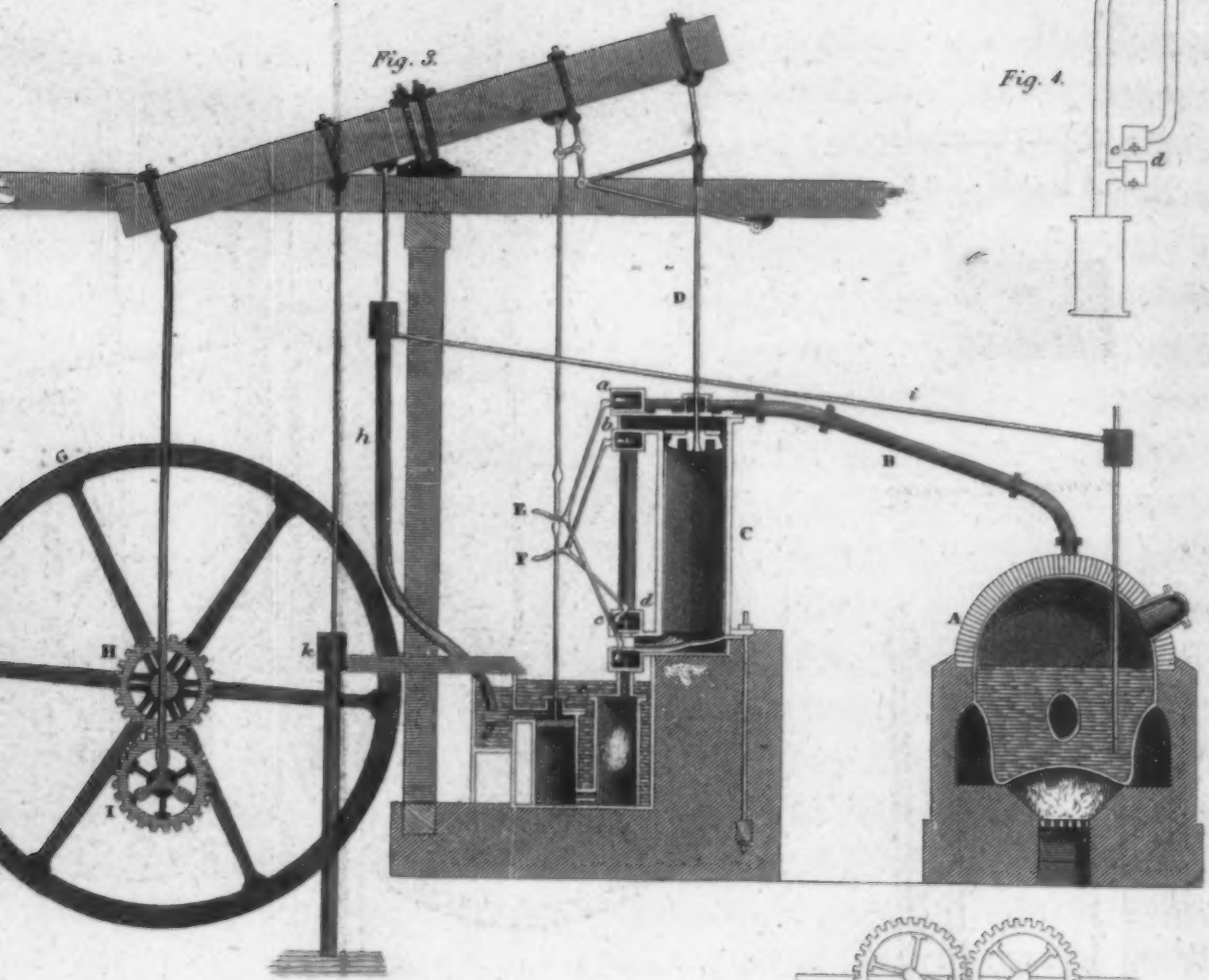


Fig. 4.

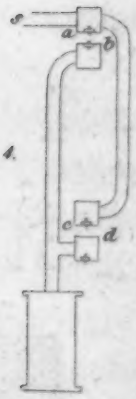
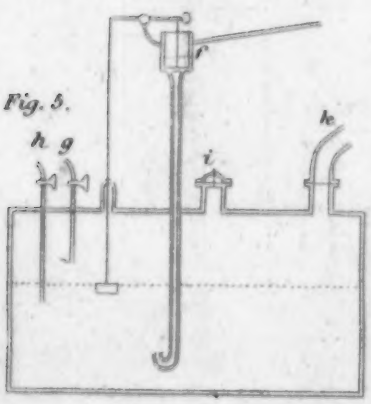
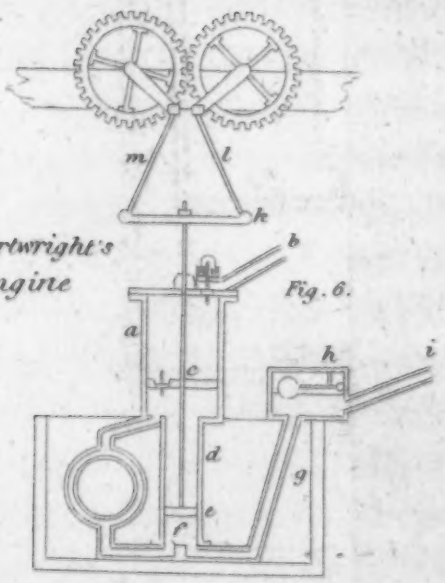


Fig. 5.



Cartwright's Engine

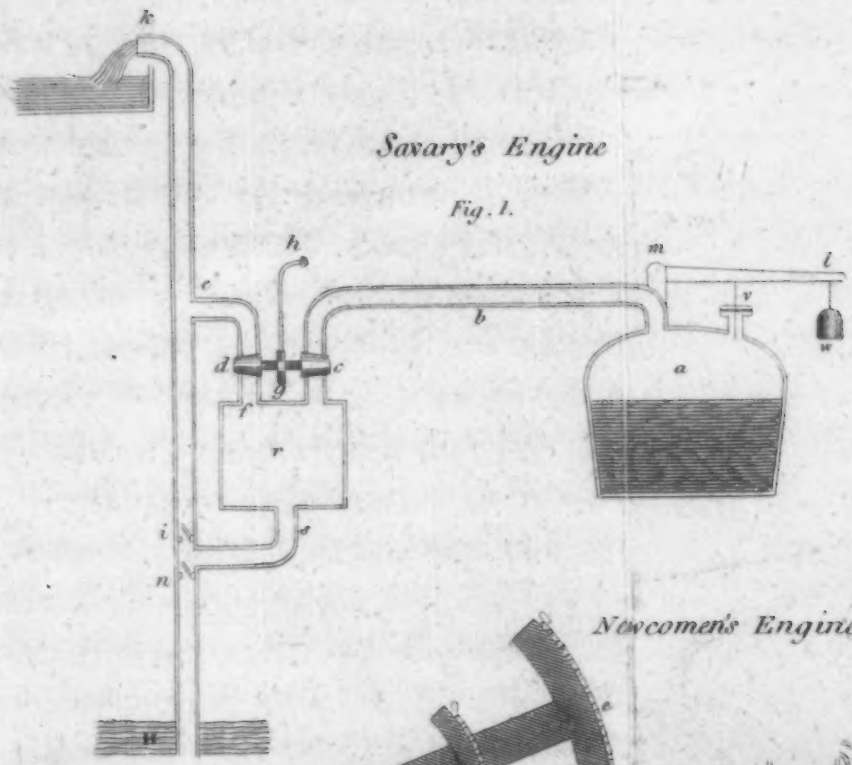
Fig. 6.



Tiebout Sc.

Savary's Engine

Fig. 1.



Newcomen's Engine

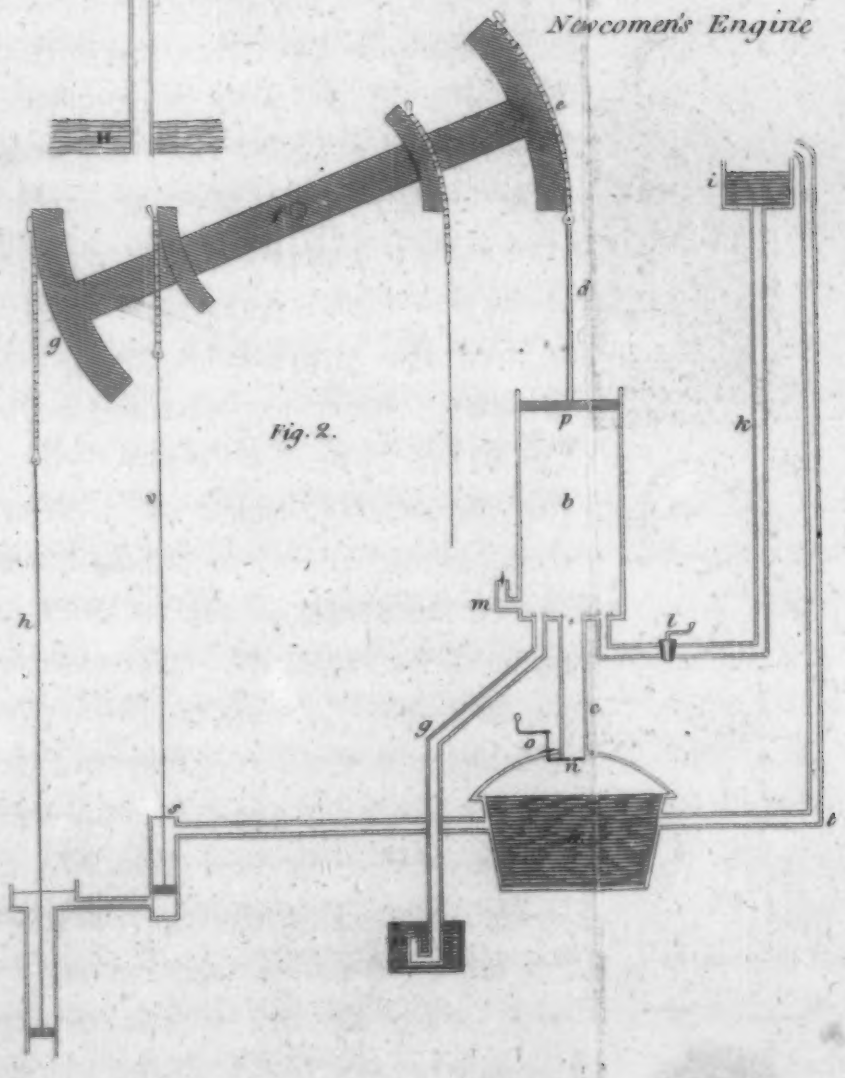


Fig. 2.

a vacuum is formed in the receiver; consequently, there is nothing to counterbalance the pressure of the atmosphere, which acting upon the water in the well, forces it up the rising-pipe, and fills the receiver. The steam-cock is now opened; and the steam from the boiler rushing in with great violence, presses upon the surface of the water in the receiver, and forcing it through the pipes, into the rising-pipe, causes it to shut the valve n, and open the other valve i; and, provided the steam be sufficiently strong, will force it up the rising-pipe to the top k, where it is delivered. The cock c is kept open until all the water be driven out of the receiver, and it is again filled with steam. The regulator is now applied, which shuts the steam-cock, whilst at the same time it opens the injection-cock. The rising-pipe being still full of water, a stream of cold water proceeds through the pipe e, and enters the receiver in a shower. This instantly condenses the steam in the receiver, and produces a vacuum as before; in consequence of which, the water from the well is again forced up by the external pressure of the atmosphere, and the receiver is again filled with water. The regulator is then turned, which shuts the injection-cock and opens the steam-cock, which permits the steam from the boiler to press upon the water, and again force it up the rising-pipe. This operation filling the receiver with water by means of a vacuum produced in it, and forcing it up the rising-pipe by the pressure of the steam from the boiler, is constantly repeated, by merely turning the regulator, which shuts and opens the steam-cocks and injection-cocks alternately.

This construction of the steam-engine is extremely simple, and might perhaps be successfully applied for some purposes. But it has several considerable defects. It may readily be apprehended, that the action of the direct steam on any definite surface (such, for example, as

a square inch) will be accurately equal to the re-action of the water which is forced up; and consequently, that Savary's engine will require steam more elastic than the air of the atmosphere, in every case except where the water is raised no higher than it can be by the vacuum that is produced, and the pressure of the atmosphere. When the water is forced up through the rising-pipe, every square inch of the boiler must sustain a pressure equal to a column of water an inch square, and of the height of the pipe above the boiler. This, therefore, requires very strong vessels, and several accidents happen by their bursting when the safety valve is loaded too much.

But the greatest defect of this machine is the great waste of steam, and consequently of fuel. For when the steam is admitted to the top of the cold water in the receiver, it is condensed with great rapidity; and the water does not begin to yield to its pressure, until its surface is so hot, as not to condense any more steam: it now descends; but as by that, a new part of the side of the receiver is exposed to the steam, more is condensed, so that a condensation of the steam is going on all the while the water is descending. This too must necessarily be re-repeated every stroke, as the receiver is cooled every time it is filled with water.

Mr. Savary succeeded in raising water to small heights, and erected several engines in different parts of England; but he could make nothing of deep mines. Many attempts have been made to correct these defects, but hitherto without much success.

In the beginning of the eighteenth century, Newcomen, an ironmonger or smith, and Crawly, a glazier at Dartmouth, in Devonshire, first conceived the project of applying a piston with a lever, and other machinery. They were contented to share the profits of the invention with

Savary, who procured a patent for it in 1705, in which they were all three joined.

Fig. 2, exhibits a section of Newcomen's engine: a is the boiler, built in brick-work. In the top of the boiler is a steam-pipe, c, communicating with the cylinder, b, which is of metal, and is bored very truly. The lower aperture of this pipe is shut by the plate n, which is ground very flat, so as to apply very accurately to the whole circumference of the orifice. This plate is called the regulator, or steam-cock, and it turns horizontally round an axis o, which passes through the top of the boiler, and is fitted by grinding to the socket, so as to be steam-tight. It is opened and shut by a handle fixed to its axis.

In the cylinder b is a solid piston, p, well fitted into it, and made air-tight by a packing of leather or soft rope, well filled with tallow; and for greater security, a small quantity of water is kept above the piston.

The piston-rod d is suspended by a chain, which is fixed to the upper extremity of the arched head e of the great lever, or working-beam, e f g, which turns on the gudgeon f. There is a similar arched head g, at the other end of the beam; to the upper extremity of which is fixed a chain, carrying the pump-rod h, which raises the water from the mine.

The load on this end of the beam is made to exceed considerably the weight of the piston at the other extremity.

At a small height above the top of the cylinder, is a cistern called the injection-cistern, i. From this descends the injection-pipe, k, which enters the bottom of the cylinder, and terminates in a nozzle pierced with holes. This pipe has a cock, l, called the injection-cock.

At the opposite side of the cylinder, a little above its bottom, there is a lateral pipe m, turning upwards at the

extremity; and there covered by a clack-valve, called the snifting-valve, which has a little dish round it, to hold water for keeping it air-tight.

There proceeds also from the bottom of the cylinder, a pipe g, of which the lower end is turned upwards, and is covered with a valve r. This part is immersed in a cistern of water, called the hot-well, and the pipe itself is called the eduction-pipe.

Lastly, the boiler is furnished with a safety valve, called the puppet-clack, in the same manner as in Savary's engine. This valve is generally loaded with one or two pounds on the square inch, so that it allows the steam to escape when its elasticity is one-tenth greater than that of the atmosphere. Thus all risk of bursting the boiler is avoided, the pressure outwards being very moderate.

When the cistern for the injection-water i, cannot be supplied by pipes from some more elevated source, water is raised by the machine itself. A small lifting-pump s, is worked by a rod v, suspended from a small arch upon the great beam; this forces water through the pipe t into the injection-cistern.

The parts of the engine being now described, the operation is as follows:

Suppose the piston and lever in the position represented in the plate, and the water in the boiler in a state of ebullition, the steam and injection-cocks being shut. Having opened the steam-cock n, the steam from the boiler will immediately rush in, and flying all over the cylinder, will mix with the air.

Much of it will be condensed by the cold surface of the cylinder and piston, and the water produced from it will trickle down the sides, and run off by the eduction-pipe. This condensation and waste of steam will go on until the whole cylinder and piston be made as hot as boiling-water.

When this happens, the steam will begin to issue through the snifting-valve, slowly at first, and cloudy, being mixed with much air; but, by degrees, it will become more transparent, having carried off the greatest part of the air which filled the cylinder.

When the attendant perceives that the blast at the snifting-valve is strong and steady, and the boiler is supplied with a steam of proper strength, appearing by the renewal of its discharge at the safety-valve, which had stopped while the cylinder was filling, he shuts the steam-cock n, and opens the injection-cock l. The pressure of water in the injection-pipe forces some out into the cylinder, which condenses the steam and forms a partial vacuum, as explained above.

The upper side of the piston is now exposed to the whole pressure of the atmosphere, which, not being counterbalanced on the under side, will act with its whole force on the piston, and, provided there be not too much weight on the other end, will raise it, the piston going to the bottom of the cylinder.

When the piston has gone down as low as necessary, the injection-cock is shut, and the steam-cock opened. The steam, which has been accumulating above the water in the boiler, during the time of the descent of the piston, and is now issuing through the puppet-clack, as soon as the steam-cock is opened, rushes violently into the cylinder, having a greater elasticity than that of the air. It therefore immediately blows open the snifting-valve, through which it drives out the air that had been disengaged from the injection-water.

At the same time, the water which had been injected before, and the condensed steam, run out through the eduction-pipe g, and lifting up the valve r, flow into the hot-well.

By the admission of the steam under the piston, the pressure of the atmosphere on the top is counterbalanced, and the piston is free to move upwards or downwards.

But the other end of the beam being broader, so as to be heavier than the piston, now raises it to the top of the cylinder, whence it is again forced downwards by the pressure of the atmosphere, as soon as a vacuum is formed under it by the admission of the injection-water. In this manner the operation is repeated; the piston being forced down by the weight of the atmosphere, raises the other end of the beam, with whatever is attached to it; and, on the other hand, when the pressure of the atmosphere is counterbalanced by the steam under the piston, the superior weight of the pump-end of the beam brings the piston up again.

We now see the difference between Savary's and Newcomen's engine, in respect to principle. Savary's was an engine that raised water by the force of steam; but Newcomen's raises water entirely by the pressure of the atmosphere; and the steam is employed merely as the most expeditious mode of producing a vacuum, into which the atmospherical pressure may impel the first mover of his machine.

We see also the great superiority of this new machine. We have no need of steam of great and dangerous elasticity; and we operate by means of very moderate heats, and consequently with a much smaller quantity of fuel: and there are no bounds to the power of this machine. How deep soever a mine may be, a cylinder may be employed of such dimensions, that the pressure of the air may exceed in any degree, the weight of the column of water to be raised. And lastly, this form of the machine renders it applicable to almost every mechanical purpose; because a skilful mechanic can readily find a method of converting the reciprocating motion of the working-beam

into a motion of any kind which may suit his purpose. Savary's engine could hardly admit of such a general application, and seems almost restricted to raising water.

Newcomen's engine was first offered to the public in 1705. But many difficulties occurred in the execution of it, which were removed one by one; and it was not till 1712, that the engine seemed to give confidence in its efficacy.

The most exact and unremitting attention was required, to open and shut the cocks precisely at the proper time; for neglect might be ruinous to the machine, by the confined steam beating out the bottom of the cylinder, or allowing the piston to be wholly drawn out of it. Stops were contrived to prevent these accidents; then strings were used to connect the handles of the cocks with the beam, so that they should be turned whenever it was in certain positions. These were gradually changed, and improved into detents and catches of different shapes; at last, Mr. Beighton, a very ingenious and well informed artist, simplified the whole of these subordinate movements, and otherwise very much improved the machine.

The greatest improvement that has since been made on Newcomen's engine, has been in the manner of placing the boiler. Instead of placing it underneath the cylinder, it is built at some distance from it, and sometimes in a separate building.

About 1762, Mr. Watt began to turn his attention to this machine, which he has since brought to so great a degree of perfection.

But before we explain Mr. Watt's engines, it is necessary to premise a short account of the imperfections of the old steam-engines, and their causes.

The steam or vapour which arises from water confined in a close vessel, and heated a few degrees above the point at which it boils in the open air, becomes an elastic fluid,

uniform, and transparent, about half the gravity of atmospheric air, very much greater in bulk than the water of which it is composed, and capable of being again reduced to water when brought into contact with matter of a less degree of heat than itself.

The pressure of the atmosphere, or any equivalent resistance, prevents the production of steam, until the water is heated to 212 degrees of Fahrenheit's thermometer; but when that pressure is removed, or the water is placed in a vessel exhausted of air, steam is produced from it when it is colder than the human blood. On the contrary, if water is pressed upon by air or steam, which are more compressed than the atmosphere, a degree of heat above 212 degrees is necessary for the production of steam; and the difference of heats at which water boils under different pressures, increases in a less proportion than the pressures themselves; so that a double pressure requires less than a double increase of sensible heat.

The experiments which have been published concerning the bulk of water when converted into steam, are erroneous; and the conclusions drawn from them make that bulk greater than it really is. It has been known for some time, that water would boil in an exhausted receiver at a low degree of heat.

If we consider the common steam-engine, we shall find it defective; first, because the vacuum is produced by throwing cold water into the cylinder to condense the steam: that water becomes hot, and, being in a vessel partially exhausted, produces a steam, which in part resists the pressure of the atmosphere upon the piston, and lessens the power of the engine. The second defect is the destruction of steam, which unavoidably happens upon attempting to fill a cold cylinder with that fluid; for the injection-water, at the same time that it condenses the steam, not only cools the cylinder, but remains there until it is extruded at the eduction-pipe by the steam which

is let in to fill the cylinder for the next stroke; and that steam will be condensed into water as fast as it enters, until all the matter it comes in contact with, is nearly as hot as itself.

Every attempt to make the vacuum more perfect by the addition of injection-water, will cool the cylinder more effectually, and cause a greater destruction of steam in the next filling; and if the engine has already a proper load, the destruction of steam will proceed in a greater ratio than the increase of power by the amendment of the vacuum.

Though it appears that the constructors of steam-engines have never investigated these causes, yet they have been so sensible of the effects, that a judicious engineer does not attempt to load his engine with a column of water heavier than seven pounds for each square inch of the area of the piston.

Mr. Watt's improvements are founded upon these, and some other collateral observations. He preserves an uniform heat in the cylinder of his engines, by suffering no cold water to touch it; and by protecting it from the air or other cold bodies, by a surrounding case filled with the steam, or with hot air or water, and by coating it over with substances that transmit heat slowly. He makes his vacuum to approach nearly to that of the barometer, by condensing the steam in a separate vessel, called the condenser; which may be cooled at pleasure without cooling the cylinder, either by injection of cold water, or by surrounding the condenser with it; and generally by both. He extracts the injection-water and detached air from the cylinder or condenser, by pumps, which are wrought by the engine itself; or he blows it out by the steam.

As the inside of the cylinder was in the old engine exposed to the air at every stroke when the piston descended, and was considerably cooled thereby, he incloses the top

of the cylinder by a metal plate, having a hole in it through which the piston-rod works in a collar of leathers; and instead of employing the pressure of the atmosphere to force down the piston, he introduces the steam above the piston, when the vacuum is formed underneath, and employs it to produce this effect: thus making the direct pressure of the steam the moving power, as in the original construction of the engine.

The last great improvement made by Mr. Watt, was his giving an impulse to the piston by the steam, both in descending and ascending, instead of being impelled, as in the old engine, during the descent of the piston only.

Having thus briefly mentioned the principal improvements made in the steam engine by Mr. Watt, we shall proceed to describe one of his engines on the latest construction.

A is the boiler, to which Mr. Watt has paid very great attention. It is generally of an oblong form; and the flame, after striking on its concave bottom, circulates round the sides, and sometimes returns in a pipe through the body of the water before it is suffered to go up into the chimney. In his engines there are commonly two of these boilers, so that one of them may work while the other is repairing. B (Plate fig. 3) is the steam-pipe which conveys the steam to the cylinder C, which is cased, and closed at top by a plate, having a collar of leathers, through which the piston-rod D works. a and c are the steam-valves, through which the steam enters into the cylinder: it is admitted through a, when it is to press the piston downwards, and through c when it presses it upwards. b and d are the eduction-valves, through which the steam passes from the cylinder into the condenser e, which is a separate vessel placed in a cistern of cold water, and which has a jet of cold water continually playing up in the inside of it. f is the air pump, which extracts the air

and water from the condenser: it is worked by the great beam or lever; and the water brought by it from the condenser, after being brought into the hot-well g, is pumped up again by the pump h, and is brought back again into the boiler by the pipe i. k is another pump, also worked by the engine itself, which supplies the cistern in which the condenser is placed, with cold water.

In the old engines, where the working stroke was only downwards, the piston-rod was attached to the beam by chains, which bent round an arch on the end of the beam, in order to make the piston-rod move always in a perpendicular direction. This may be seen in the plate of Newcomen's engine. But in Mr. Watt's engines, where the working-stroke is doubled, that is, both upwards and downwards, chains could not answer this purpose, as, when the piston was forced upwards, they would slacken, and would not communicate the motion to the beam. It was necessary, therefore, that the piston-rod should be fastened to the beam by inflexible bars; but that the stroke might be perpendicular, a particular contrivance was invented by Mr. Watt, which is exhibited in the plate, and which answers the intended purpose admirably. It is usually called the parallel joint, and its nature and construction will be easily understood from the figure. In order to make the engine itself open and shut the steam and eduction-valves, long levers are attached to them, which are moved by the piston-rod of the air-pump E F. This part of the apparatus is called the working-geer, and is so contrived, that the valves may be worked either by hand or by the perpendicular rod. By shutting these valves, the engine may be stopped in an instant.

In order to communicate a rotatory motion to any machinery by the motion of the beam of the steam-engine, Mr. Watt makes use of a very large fly-wheel G; on the axis of which is a small concentric toothed wheel, H. A

similar toothed wheel I, is fastened by straps to a rod coming from the end of the beam, so that it cannot turn round on its axis, but must rise and fall with the motion of the great beam.

A bar of iron connects the centres of these two small toothed wheels, so that they cannot quit each other. When, therefore, the beam raises the wheel I, it must move round the circumference of the wheel H, and turn it together with the fly; and it will be evident, upon consideration, that the fly, driven in this manner, will make two revolutions for every one of the wheel I. This mode of moving the fly, is preferable to a crank; as it goes with twice the velocity. This contrivance is called the sun and planet wheel, from the resemblance of the motion to that of those luminaries.

The valves of this steam-engine are all puppet-valves, as these are found least liable to be out of order.

The mode of operation in Mr. Watt's engine, is as follows:

Suppose the piston at the top of the cylinder, in the situation represented in the plate, and the lower part of the cylinder filled with steam. By means of the handle E, open the steam-valve a, and the eduction-valve d, the levers of which are connected together; there being now a communication between the cylinder and the condenser, the steam instantly rushes into the condenser, leaving the cylinder empty; whilst at the same time the steam from the boiler, entering by the steam-valve a, presses upon the piston and forces it down. As soon as the piston has arrived at the bottom, the steam-valve c, and the eduction valve b, are opened, whilst the valves a and d are shut; the steam therefore immediately rushes through the eduction-valve b, into the condenser, whilst the piston is forced up again by the steam, which is now admitted by the steam-valve c.

Fig. 4, which is a section of the steam-pipes, taken at right angles to that in fig. 3, shews this more distinctly; s is the pipe which conveys the steam from the boiler; a and c are the steam-valves, and b and d the eduction-valves. By attending to the operation in both the sections, the reader will easily understand it. It appears at first a little confused, by there seeming to be only one steam-pipe for communicating between the cylinder and the condenser; but the difficulty is cleared up, by representing both the pipes, as in fig. 4.

Fig. 5, is a longitudinal section of the boiler, representing the mode of supplying it with water, and the safety-valve and cocks. f is a small cistern, which is supplied with water from the hot-well, as represented in fig. 3; from the bottom of this cistern, a pipe goes down almost to the bottom of the boiler, where it turns up a little, to prevent the entrance of the steam which rises from the bottom. From the side of this cistern, is supported a small lever, to one end of which is fastened a wire, that carries a stone which hangs in the water of the boiler; the other end of the lever supporting also by a wire, a valve that shuts the top of the pipe that goes down from the cistern. Now, supposing the stone just at the surface of the water, and balanced by a weight at the opposite end of the lever; it is evident, that by the laws of hydrostatics, already explained, a certain part of the weight of the stone will be supported by the water, so long as it continues immersed in it; but if a part of the water evaporate by boiling, a proportional part of the stone will be above the water, consequently the stone will bear more upon the lever and raise the weight at the other end; but in raising that weight, it also opens the valve in the small cistern, and admits water until it stand at the same height in the boiler as before, and then the valve and the stone being again in equilibrio, the valve remains shut until a

new quantity is evaporated. By this means the supply of water is very gradual, however, and not by fits and starts, as here described for the sake of illustration.

It is found by experience, to be a much better method than a ball-cock, and the regular supplying of the boiler with water is of the first importance. As a check upon this, and to know perfectly the height of the water in the boiler, there are two cocks, g and h, one of which reaches nearly to the surface of the water when at its proper height, and the other enters a little below the surface.

It is evident, that if the water be at the just height, and you open g, steam will issue; and if h be opened, water will be driven out by the pressure of the steam. But if water come out from g, then the water must be too high in the boiler; and if steam issue from h, then the water is too low. By this means, it is easy to know at all times the exact height of the water in the boiler.

i is a safety-valve, to prevent the bursting of the boiler by the steam growing too strong; k is the pipe which conveys the steam to the engine.

Fig. 6 is Mr. Cartwright's steam-engine, the construction of which evinces much ingenuity. a is the cylinder, which is supplied with steam from the boiler through the pipe b; c is the piston in the act of going up; d is the pipe that conducts the steam into the condenser e, *which consists of two cylinders, one within the other, leaving a small space between them, into which the steam is admitted;* while the inner cylinder is filled with cold water, and also the external cylinder surrounded by the same; so that, by this means, a very large surface of steam is exposed, though no water is suffered to come into actual contact with it.

To the bottom of the piston c, is attached a rod, with another piston e, working in the pipe d. When the pis-

ton e arrives at the bottom of the cylinder, a valve which is in the piston, is opened by its pressing against the bottom, and opens a communication with the condenser, whilst the spring k, fixed to the rod of the piston, shuts the valve which admits the steam from the boiler. The steam, therefore, being thus condensed, runs into the lower pipe f. The piston e, arriving at the bottom of the pipe in which it works at the same time with c, presses upon the condensed water, shuts the valve f, and forces the water up the pipe g, into the box h. The air which is disengaged from the water, rises to the top of the box, and, by its elasticity, forces the water through the pipe i, which carries it back again into the boiler. When the air accumulates in the box to such a degree as to depress the water, the ball-cock falls with it, and opens a valve in the top of the box, which suffers some of the air to escape.

When all the steam is condensed, the motion of the fly attached to the machine brings the piston up again, its valve now remaining shut by its weight. On arriving at the top, it presses up the steam-valve, which admits the steam from the boiler to force it down as before.

l and m are two cranks, upon whose axis are two equal wheels working in each other, for the purpose of converting the perpendicular motion of the piston-rod into a rotatory motion, for working the machinery attached to it.

But the most valuable part of this engine is in the construction of the piston, which Mr. Cartwright made wholly of metal, and so as by means of springs, to fit the cylinder very exactly. This not only saves the expence and trouble of packing, which they are obliged frequently to renew in all other engines, but also saves a great deal of steam, on account of the more accurate fitting of the piston.

As it is evident, from its construction, that the whole of the steam is brought back again into the boiler, it affords the means of employing ardent spirit instead of water, and thus saving a great deal of fuel.

This machine seems to be peculiarly applicable to purposes requiring only a small power, as it is not expensive, and occupies little room.

It would far exceed the limits of this work, to enter into an examination of all the steam-engines invented by different persons. It is sufficient to mention, that no engine of this kind has been found, upon careful trial, to be superior to those of Mr. Watt.

From this brief description of the steam engine, the reader will be enabled to perceive the nature, and appreciate the value, of Mr. Watt's improvements. It had hitherto been the practice to condense the steam in the cylinder itself, by the injection of cold water; but the water which is injected acquires a considerable degree of heat from the cylinder and being placed in air highly rarefied, part of it is converted into steam, which resists the piston, and diminishes the power of the engine. When the steam is next admitted, part of it is converted into water by coming in contact with the cylinder, which is of a lower temperature than the steam, in consequence of the destruction of its heat by the injection-water. By condensing the steam, therefore, in the cylinder itself, the resistance to the piston is increased by a partial reproduction of this elastic vapour, and the impelling power is diminished by a partial destruction of the steam which is next admitted. Both these inconveniences Mr. Watt has in a great measure avoided, by using a condenser separate from the cylinder, and encircled with cold water; and by surrounding the cylinder with a wooden case, and interposing light wood-ashes in order to prevent its heat from being abstracted by the ambient air.

The greatest of Mr. Watt's improvements consists in his employing the steam both to elevate and depress the piston. In the engines of Newcomen and Beighton, the steam was not the impelling power: it was used merely for producing a vacuum below the piston, which was forced down by the pressure of the atmosphere, and elevated by the counterweight at the farther extremity of the great beam. The cylinder, therefore, was exposed to the external air at every descent of the piston, and a considerable portion of its heat being thus abstracted, a corresponding quantity of steam was of consequence destroyed. In Mr. Watt's engines, however, the external air is excluded by a metal plate at the top of the cylinder, which has a hole in it for admitting the piston-rod; and the piston itself is raised and depressed merely by the force of steam.

When these improvements are adopted, and the engine is constructed in the most perfect manner, there is not above $\frac{1}{4}$ part of the steam consumed in heating the apparatus; and, therefore, it is impossible that the engine can be rendered $\frac{1}{4}$ more powerful than it is at present. It would be very desirable, however, that the force of the piston could be properly communicated to the machinery without the intervention of the great beam. This, indeed, has been attempted by Mr. Watt, who has employed the piston-rod itself to drive the machinery; and Mr. Cartwright has, in his engine, converted the perpendicular motion of the piston into a rotatory motion, by means of two cranks fixed to the axis of two equal wheels which work in each other. Notwithstanding the simplicity of these methods, none of them have come into general use; and Mr. Watt still prefers the invention of the great beam, which is generally made of hard oak, with its heart taken out, in order to prevent it from warping. A considerable quantity of power, however, is wasted by dragging

at every stroke of the piston, such a mass of matter from a state of rest to a state of motion, and then from a state of motion to a state of rest. To prevent this loss of power, a light frame of carpentry has been employed by several engineers, instead of the solid beam; but after being used for some time, the wood was generally cut by the iron bolts, and the frame itself was often instantaneously destroyed. In some of the engines lately constructed by Mr. Watt, he has formed the great beam of cast iron, and while he has thus added to its durability, he has at the same time diminished its weight and increased the power of his engine."

(To be continued.)

POLITICAL ECONOMY.

The following dissertation by DR. E. BOLLMAN is too good to be broken into parts: I publish it therefore together. If any of my readers are displeased with discussions on this subject, I am sorry for it. I shall hardly be shaken in my opinion, that I can insert no subject of a miscellaneous nature so important. T. C.

VINDICATION OF FOREIGN COMMERCE.

DEAR SIR,

Agreeable to your permission, and, in discharge of the engagement which I have in some measure contracted with your readers, in consequence of the publicity you were pleased to give to my letter of the 16th of June, I am going to communicate to you a few remarks in vindication of foreign commerce. I shall endeavour to state them, with as much brevity, as the subject will admit of, without becoming obscure.

In all disquisitions on topics of political economy, we should constantly keep in mind, as the standard, by a reference to which the soundness of every proposition, or maxim, is to be *tested*, the probable effects of such proposition, or maxim, when put in practice, on the productiveness of labour.

The *real tacit aim* of all national exertions, so far as they consist in the sum general of individual efforts—; and the aim, to which all measures of government, with regard to national industry, ought ultimately, and unequivocally to tend, is, THE ATTAINMENT OF THE GREATEST RESULTS, AT THE LEAST POSSIBLE EXPENCE.

Whenever this point has been accomplished, a limited number of inhabitants, in any given country, will exist in the greatest state of prosperity, and wealth, of which, with their soil, their moral and physical qualifications, they are susceptible; OR, the largest possible number will be supported by the same country, in a state—exempt at least from wretchedness.

Since misery limits population, both these tests of the good economical organisation of a country, are, in fact, the same. The government which should have caused, either a truly living, not starving, and languishing population, to attain its maximum—or a limited population to enjoy the greatest share of affluence—would have reached perfection in the eye of the political economist. No government can do more.

If, therefore, the respective value of the different kinds of commerce, and the true policy of governments, with regard to commerce, are under consideration, we must refer to the same rule, the decision of the abstract question.

And, with the abstract question, examined on theoretical grounds, I shall occupy myself in the first instance. Not from any particular predilection for this mode of investigation, but from a conviction, that we are, generally speaking, less liable to err, by reasoning closely, from correct principles, than by appealing at once to a mass of facts, always difficult to *collect correctly*, and extremely difficult *correctly to understand*.

All commerce arisies from division of labour. If every family, by their own industry, could provide for the gratification of all their wants, there would be no need for exchanges. Nothing would be sold, or bought. But experience has taught mankind that their condition improves by their working for each other. The greatest degree of civilization, and prosperity, *implies mutual dependence*. The individual who should attempt to realize a strict independence, would soon, like his prototype of old, become dirty, sulky, churlish, gross. The perfectability of human nature is only developed in the social state; and from this first glance of the

subject, we are already led to presume that a nation, when trying to withdraw from the great society of nations, and to suffice to herself, assumes a situation, probably not the most favourable for the attainment of either, civilization, or prosperity.

In order to reason with accuracy, we should distinguish in Commodities *four* descriptions of value.

The *intrinsic*, or philosophic value, which is determined by usefulness. In this respect iron and grain are commodities of infinite value. The diamond would be destitute of any, if it did not cut glass.

The *Labour-value*—which is derived from the quantum of work required, to bring a commodity into existence. Some highly finished productions of the arts exceed in this species of value all others, though their market price is often very low. The celebrated Portland-vase, according to the opinion of *Wedgewood*, must have consumed the unabated industry of a whole life, and perhaps of more lives than one.*

The *commercial-value*—which is the value of a commodity in exchange, for the circulating medium of commerce. This value should be always understood, when value is simply mentioned. It may be considered as the only *practical* value; and it is solely regulated by the supply and demand in the market, as well of the commodity exchanged, as of the circulating medium, by means of which the exchange is effected.

Commodities finally have a fourth description of value, which has not, to my knowledge, been distinctly noticed by any of the writers on political economy, and which, yet is of importance. I mean their *relative value*, with regard to those who actually have, or seek possession. It depends entirely on their *habits*, *circumstances*, and *feelings*. Of course it varies ad infinitum.

The great, and constantly changing difference in the *relative value* of commodities is the cause, and the very *simple cause*, of all existing commerce, to account for which, the luminaries of our science have singularly ransacked their brains; some, like Adam Smith,† seeking for its origin in a peculiar propensity of mankind to truck, and barter; in a sort of commercial instinct; others, in certain prevailing vices of the mind.

* Darwin's Botanic Garden. Part I. Canto II. Note xxii.

† Wealth of Nations. Vol. I. Book I. Chap. 2.

All that lives is stimulated by one universal passion—the desire to experience, to multiply, and to prolong, agreeable sensations. Man in particular, constantly seeks to improve his condition. This passion accounts for the existence of commerce, as for the existence of every other social phenomenon, whether beneficial, or destructive.

The commercial value of a commodity may be considered as *fixed*, at every given place, and period. Every article, if it sell at all, has its price. But the differences of relative value are *endless*.

If the price of a good watch, for instance, be a hundred dollars, and I purchase one for that price, it is obvious that I attach myself a greater importance to the possession of the watch, and the seller to that of the money; otherwise the transaction would not take place. On the other hand, it must take place, as soon as we meet, and come to a mutual explanation, since he feels less anxious to retain the watch, which I covet, than to become the owner of my hundred dollars, which I am willing to part with.

A man, returning from a long journey, and wishing to enjoy repose at home, may no longer have occasion for his horse. His neighbour, perhaps, is just preparing for a journey, and tries to find a horse, on which he can depend. If both happen to see each other, and discover how they stand mutually affected, the one will necessarily part with his horse, the other with his money, without either being impelled by any peculiar trading instinct; and both will be the better for having done so.

The difference of the relative value of commodities, therefore, or, in other words, the different degrees of consequence, attached by various individuals to their possession, is the prompter to all commercial intercourse. The thing acquired, is always preferred by the receiver, to the thing parted with in exchange; and *both parties to the transaction generally are gainers.*

It is further obvious, that the amount of their respective gains, is in exact proportion to the degree of difference in the relative value of the things exchanged.

To a manufacturer, the relative value of the commodities he brings to market, is simply equal to the expence incurred for procuring the raw material, the quantum of labour bestowed on it, and the interest of the capital employed. These items make up what the articles *cost* him; and as he made them for sale, no particular importance can be attached, by him, to their possession. If their relative value with the consumers is very great, he will, of

course, be able to obtain for them an *excellent* price. The better the price, which he is able to obtain, the greater will be his advantage. For either, less labour will be sufficient to provide for his wants, if these be circumscribed; or, the unabated, usual exertions, will the more surely, and rapidly, procure him wealth.

Thus we see, that the profits of mercantile transactions arise from the difference of the relative value of the commodities exchanged; among which we must not forget to include the circulating medium itself.

Whoever, therefore, produces any commodity, or causes it to be produced by the labour of others, or acquires the products of labour for money, with a view to dispose of them again, must be anxious to exchange them with those, with whom their relative value is the highest. The better he succeeds in this, the more will his exertions, generally speaking, be beneficial to himself, and to the state.

We have now to ask, in what situation the differences of relative value are likely to be greatest,—Whether when the members of a community trade only among themselves, or, when they exchange their productions with foreign nations?

But, diversity of relative value, arises from diversity of taste, habits, talents, skill; from peculiarities of the soil occupied; from conveniences of locality; from the nature, and quantity, of spontaneous productions at hand; from the difference of climate, of government, of the state of civilization, &c. &c.—These must exhibit stronger contrasts between distant nations, than between individuals of the same political family. Therefore *foreign commerce*, considered abstractly, that is, barely in reference to gain, *must, unquestionably, be more* beneficial than domestic commerce.*

I shall shew more fully in what the advantages of foreign commerce *chiefly* consist; and what a country sacrifices by relinquishing, or neglecting, the intercourse with distant nations.†

* Patterns and commodities, are more frequently new, abroad, than at home, and novelty always induces an increased relative value; but novelty in commerce is momentary only; and accidental: for so soon as a new article is found to fetch an extraordinary price, the market becomes always stocked, generally glutted with it. Foreign commerce therefore, reasoning *in the abstract*, has no permanent beneficial qualification over home trade. When we recur to matter of fact, the argument falls at once to the ground: for whenever foreign becomes sensibly more beneficial than home trade, it draws to itself capital, that brings on the usual level. T. C.

† The question is not, whether foreign commerce ought to be relinquished or neglected, but whether the citizens who pursue it, have a right to protec-

Foreign commerce is beneficial

1. *Because it brings into operation the advantages which may be derived from the different value of the precious metals, in different countries.*

The precious metals, now the general medium of circulation in the civilized world, may be considered, as possessing a fixed value, in the *same country*, at the *same period*, which is solely regulated by the proportion of their supply, to the exigencies of the public. But their value is by no means the same in all countries. In one, money may be scarce, while it abounds in another. The home-value of money, at each time, is settled; its *relative national value*, at the same time, is various. This is *one* cause of the difference of prices of commodities in different countries; a difference giving birth to favourable exchanges,* renouncing the benefits of which will be lost to a nation renouncing foreign trade

The precious metals abound in Mexico, whilst our manufacturers, and mechanics, excell in skill and knowledge, those of that country. Even our flour, so readily transported, is more within reach of the people at Vera Cruz, than their own, which descends to them, on the back of mules, from the plains producing it, six thousand feet above their level. † Our cabinet ware, our saddlery, our flour, and many other commodities, might, of course be favourably exchanged for silver at that place. With this silver we might procure East India muslins, teas, nankeens, and china—very de-

tion at great distances from the national territory—at an expence which no reasonable calculation of commercial gain can ever repay—and at the perpetual hazard of war, induced by commercial monopoly, commercial jealousy, and commercial fraud. Especially, as these have notoriously proved during a century and a half, the most sure and productive causes of modern warfare. It is not pretended by any person whatever, so far as I know, that foreign commerce should be either abandoned or neglected, while it can be safely, and productively pursued—without involving the consumers at home, in the expence and deprivation attendant upon commercial hostilities, to protect the speculation, and ensure the profits of the merchants abroad. T. C.

* The commerce depending upon fluctuations in the value of bullion in Europe (*even* since the depreciation of paper currency in England) is so trifling as to be perfectly insignificant in a national point of view. The course of exchange depends, not on the relative values of bullion, which influence it but in a slight degree; it depends on the right of one nation to draw on another for the balance of mercantile transactions. T. C.

† Alexander de Humbold, Political Essay, on the kingdom of New Spain.

sirable commodities, the enjoyment of which we must forego,* if we stay at home.

2. *Because it brings into full, and extensive operation, productive of wealth—all the advantages peculiar to a country, physical, as well as intellectual and moral.*

Without foreign trade, every natural, or attained advantage of a country, however great, or peculiar, is only improvable commensurately with the consuming capacity of its inhabitants.

If Pennsylvania, for instance, contained an abundance of clay, flint, and other materials for pottery, superior in quality to any other in the world, the Pennsylvania pottery would not, on that account, if never exported, command any extraordinary price at home. *Nothing can procure an advantage in exchange that is common to all.* From the supposed abundance of the good material, and the necessary effects of competition, the pottery would be brought to market at the lowest price, at which it could be afforded, so as to yield a living to those engaged in the business. But, if the sales of Pennsylvania pottery, from the preference given to the ware, extended to all the civilized portions of the earth, it might so happen that the supply could not keep pace, with a demand so vast, which would cause an increase of price, and a greater proportionate gain.† Or, if the supply kept pace with the demand, and the prices remained unaltered—still thousands of potters would owe a comfortable subsistence to the clay, instead of a few hundred only, whom the business at most could have supported without exportation.

Nor would other trades be deserted, on account of the great

* Not at all: the nations who have them, will bring them to us, if we have wherewithal to pay for them. Are not we ourselves so anxious to export these articles, that our merchants complain incessantly of Great Britain who will not permit us to sell them in the West Indies for Rum and Sugar, in Holland for Gin, in Italy for Anchovies and Olives, and so on? T. C.

† All these supposed advantages of foreign commerce, proceed upon the supposition, not of reasonable, but unreasonable gain: a circumstance that always and inevitably, works its own destruction. Or, of an over-populated country, that calls for every possible exertion and every source of employment to keep its inhabitants from starving. This may be the case in England, but cannot be so here for a long time to come. Nor is it true, that what is common to all, can procure no advantage in exchange. Labour judiciously and industriously bestowed, can give exchangeable value to any material however common, in the home as well as in the foreign trade. Connecticut can sell her tubs, her onions, her coffins, even in the United States: so can Rhode Island her straw bonnets, her cotton twist, her home made woollen, &c. T. C.

numbers required for the potteries. *Men appear as they are wanted.* And all the potter's needs must eat, and be lodged, and clothed.

Besides potters, what a large number of other people—carriers, packers, dray-men, brokers, merchants, underwriters, shipbuilders—what a host of artists, and tradesmen, concerned in furnishing the materials for ships, and in equipping them—all would more or less, derive support and affluence from the clay.* For, if our pottery, in the supposed case, were exported in our own vessels, the foreign consumer, besides the labour of the potters, and the value of the materials, would have to pay the merchant's commission, the merchant's profit, small charges, insurance, and freight—which items are included in the price the exported article must bring abroad. If it did not bring this price, the exportation would discontinue.

Further—in consequence of all this industry which the clay puts in motion—what a mass of additional livers, to consume, and give value, to the produce of the farmer.

We have no such clay in Pennsylvania. But, does the same reasoning not apply to every article which we are in the habit of exporting; to our flour, to our pork, to our flax seed? Do they not all bring abroad their cost, and the enumerated charges! Does it not strictly apply to the cottons, the tobacco, the tar and turpentine of the south? to the fish, and the potash of the north?†

* All this is very true; but is there no method of employing the same number of people and the same quantity of capital in the home trade? The case put, of a Potter, is a very unfortunate one; for so far from wanting an export trade for our pottery, we do not supply the 1000th part of our own consumption in pottery, except of the very coarsest and least valuable kind. When the time shall arrive, if it ever do, that no employment for our people or our capital remains at home, then it may be worth discussion whether we may not as well encourage employment from abroad by direct means, and at any hazard. At that period of time, and not sooner, will the argument in favour of the direct encouragement of foreign commerce really become a subject of important discussion. T. C.

† I see no difficulty in manufacturing a great part of our flax seed into linen—of our cotton into cloathing, and carpets, and sail cloth, and bagging—our potash into soap and glass, and employ it in bleaching and dying. If we did so, our flour and our pork would not spoil upon our hands. But in this, as in all other particulars, the question is, can you manufacture it, or export it, to the greatest advantage? If you can export it to more advantage, do so; but do not tax us, the consumers, with the expence and inconvenience of a war to defend your gains in the export trade, when no such expence or inconveni-

—We had always plenty to eat. If all the cotton and tobacco lands are turned into wheat fields, the flour must necessarily spoil on our hands. Nor could we possibly manufacture up all the cottons, which we exported, to the amount of nine millions of dollars per annum, were they within our reach; nor chew and smoke all the tobacco, cook all the fish, turn all our potash into soap and glass, or find possibly any use whatever for the tar, and turpentine of our forests.

Let it not be imagined that we loose nothing, because we do not yet seem to suffer. We slowly consume our past accumulations, while we throw on posterity the cost of our folly. To stop in the career of prosperity, is to retrograde: and a corrected policy, with redoubled exertions, will, for a long time, strive in vain, to attain that eminence of national wealth and power, which, but for our want of wisdom, we might have occupied.

There are many productions with us, as in most other countries, which, where they grow, or are found, have little or no value, but which may be exchanged to great advantage abroad.—No body here uses ginseng, but it commands in China commodities, the possession of which is desirable. Our oak-bark is of little use to us, and could hardly be consumed even if all the nation were to dress in yellow*; in England it was exchangeable for objects we want. The trimmings of our sheet-iron accumulate in large heaps round our rolling-mills; the Chinese gave us silks for them. The leeches of the ponds round our city—to the amount of 15 to 20,000 per annum, were exported to the West Indies, and made several thousand dollars circulate in this neighbourhood. How is the community to be indemnified for their loss, unless indeed you were to imagine that they ought to be let loose on the redundant blood of our own citizens, to

ence need be incurred by or on account of any citizen employed in the home trade. Go abroad: at your own risk: if the profits will pay the insurance, go on: if not, employ yourself and your capital at home. There are manufactures to establish without number; a population to be supplied incessantly calling for your articles; lands to cultivate without limits; employment for money and for people, that centuries will not satisfy. T. C.

* It is granted, that the nation gains by exporting articles that yield a profit abroad and none at home. But let us not set up a man of straw, and exult in the victory of demolishing him. The question is not, shall we export useless articles, or keep them at home to spoil and waste—the question is, do we pay too much or not, for the profit they bring? Under what circumstances and conditions can the export be *prudently* made? T. C.

make them eat more, to replace the waste, and thus to stimulate agricultural industry by an increased demand for food!

There have been exported from new Spain upwards of two thousand millions of silver dollars, since the first discovery of that country, and agriculture flourishes most in the vicinity of the mines.* Of what use to the people would have been all this metallic treasure if not exported?—Cochenille, Jesuits-bark, Vanilla, the most valuable spices, are the spontaneous productions of the countries whence we receive them. A considerable commerce is carried on in Swallow nests from Cochin China to China.†

If some nation had as great a fancy for dried oak leaves as we have for tea,‡ and would give us commodities, on which we set value, in return for them—will any one be so mad as to say, that we should gain nothing by their sale abroad? Would not millions of people derive support and comfort from gathering, and preparing them for the market? The country thickly settled, and other things remaining unchanged, must they not starve, and perish, if their exportation were to cease?§

* Alexander de Humbold, in the work mentioned before.

† Barrow's Travels to China.

‡ Do the Chinese need a foreign trade of merchant ships protected by ships of war, to sell their tea? Can any example be more in point, to shew, that if you possess commodities of value to give in exchange, the merchants of other countries will let you want for nothing? Still I am no advocate for imitating the Chinese. Shew me that your foreign trade, yields a reasonable profit, after all the expences of the merchant are paid, and all the expences of the *nation* are paid, and then I agree, it is well worth pursuing. If a merchant gain 20 per cent. on his capital, and a farmer gain 20 per cent. on his capital, the consumer not only pays the mercantile profit of 20 per cent, but for the most part of 50 per cent. more to protect the merchant's speculation. T. C.

§ I hardly know how to suggest a stronger argument against the *encouragement* of foreign commerce than this suggestion of Dr. Bollman, in favour of it. If manufacturers at home are made absolutely dependant for subsistence, on customers abroad, whom accident, caprice, poverty, competition, war, may strike off—then shall we frequently behold, as of late years in England, famine pervading the land, and thinning the ranks of that class of the community, who might be made the main strength of the nation. In Great Britain, within these six years, at least half a million of wretched manufacturers would have starved, if war had not invited them to the wretched alternative she holds out. The war itself, in which that nation has been involved, has not produced altogether so much evil in other respects, as in making the poor manufacturers feel so cruelly, the lot of those whose bread depends upon foreign trade. T. C.

If all the West-India islands belonged to one sovereign, and he should, miraculously, happen to be a wise man—can it be for one moment conceived that he would attempt to increase his power, and promote the prosperity, and wealth of his subjects by causing them to raise sugar, coffee, and the other productions, peculiar to those climates, only in sufficient quantity for their own consumption, and to procure sparingly, imperfectly, at a vast expence of labour and time, or totally to forego those enjoyments, and that wealth, which attention to the productions most favoured by their tropical situation, and their unrestrained exportation would procure to them in abundance, and with ease?*

The condition of France cannot be thought to have improved, because she is obliged, in compliance with Napoleon's mandates, to extort from a crop of five acres cultivated in beets, as much indifferent sugar as the wheat of one acre would procure from abroad of an excellent quality.†

We have hardly, in our wealthy country, a sufficient quantity of rags to supply us with paper. But Italy could not consume the paper which her inexhaustible rags, were she to work them up herself, would bring into existence. She exchanges them for West-India produce and hard ware. She does the same with the alum, the sulphur, the puzzolana‡ of her burning mountains.

All my readers probably know, that the current of opinion among the literati of England, and especially of the reviewers, such as the Edinburgh, and the Monthly, is opposed to the prevailing madness for foreign commerce. The Edinburgh Review moreover, conducted with much ability, is generally in opposition to the present politics of the British government. To counteract the effect of the disquisitions in that review, the Quarterly Review was set on foot, as a general defence of the measures of government in church and state. Yet even the Quarterly Review, is struck with the manifold misery of which a dependance on foreign commerce is at one time or other the inevitable cause. I will put in a note to the end of this paper, the extract to which I allude.

* No. I am a fixt advocate for raising every thing that can be sold or bartered with profit. I greatly approve of unrestrained exportation. Let the merchant carry what he pleases, where he pleases, *at his own risk*. If his trade be hazardous, it is his own affair: it is his duty to sit down and count the cost: he has no claim upon the nation to take the hazard upon itself. T. C.

† But sugar sells in France for 15 sous. The dollar passes for 108 sous. That is about 7¼lbs. for a dollar. T. C.

‡ The Puzzolana or Terras, is hardly now an article of export: its use is superceded by the admixture of Smithy-slack and the cheap oxyds of iron with mortar. T. C.

Shall those, who are thus supported, be abandoned to misery, that the anticommercial system may flourish?

The agriculture of Sweden is inadequate to the maintainance of her people;—shall part of them be driven off, because they cannot learn to digest copper and iron?—must the island of Madeira be evacuated, because no longer permitted to send abroad her forty thousand pipes of wine?—must Geneva become a village, because no longer allowed to supply the world with watches?*

Due efforts will be attended with the greatest success, when bestowed on that branch of industry for which the country from its physical condition is best calculated. The more this can be exclusively followed, the greater will be the wealth acquired. It must therefore be the interest of every nation to extend the markets for her staple commodity to the most distant regions.

In the same manner, intellectual and moral acquirements will become productive of greater national benefits, when displayed on the theatre of the world, than confined to the narrow sphere of domestic concerns. The probity and fairness in dealing, for which it is said, that British manufacturers are distinguished, promises to them no exclusive advantage at home, but insures a preference among foreign customers. Confidence abroad, and the command of foreign funds, are happy results of an impartial execution of the laws. Public faith makes public credit an exportable commodity; and insures to younger nations, a participation of the benefits arising from the large capitals of the old. Banking is not less lucrative and eligible when transacted among nations, than as a business among individuals.—Skill, credit, character, ingenuity, activity, prudence, which lead to fortune in private pursuits, must yield still greater results when nationally pre-eminent in extensive commercial concerns. Correct, and minute information of the wants of mankind in every spot, is of itself, a most powerful engine of wealth, but it can neither be acquired, nor rendered valuable, without a foreign trade.

* It is a great misfortune when the existence of a people depends upon the sale of articles, which their customers can dispense with whenever they please and without inconvenience; and in which, other nations may so easily become competitors. This I have already averted to. T. C.

3. *This trade is beneficial because it contributes materially to carry the division of labour, and the introduction of labour-supplying machinery to their greatest extent.**

The object of all labour being the gaining of a subsistence, it cannot be expected that any man should devote himself, exclusively, to any particular branch of industry, unless the demand for the article produced, or raised, be sufficient to insure him a remuneration adequate to his exertions.

In an isolated settlement, consisting of eight or ten families, no one could be a miller, because the trifling demand for flour could not afford him employment, and support. For the same reason such a settlement could not support a shoemaker. The man who should grind the grain, or make the shoes for his neighbours, would at the same time be obliged to follow some other profession, or employ part of his time in farming. Should the growth of the settlement at last allow a man to devote himself exclusively to the working in leather, still he would be obliged to make men's shoes, women's shoes, children's shoes, and boots. In a still more populous community, all those subdivisions of shoemakers would become distinct branches; till finally some hands would make only a particular description of men's, others of women's and children's shoes—even the binding of them would become a distinct trade, and it is at this period that the public generally, would be supplied with the best shoes, of every description, at the lowest prices.

The same observations apply to every other trade, and pursuit. They also apply to the introduction of machinery.

Most machines perform but one operation. In order to warrant the investment of capital in the construction, or acquisition, of a machine, it is necessary that the performance of that operation should recur sufficiently often to enable the machine to earn the interest of the money it cost, and a profit besides.—A farmer, who cultivates a few acres only, will not think of having a thrashing machine.—The consumption of a few plates of sheet iron, of a few nailrods, will not warrant the construction of a rolling and slitting mill.

* Not more from an encreased demand abroad, than from an encreased demand at home. In point of fact, the best finished and more costly manufactures—those that incite chiefly to improvements in machinery, are seldom exported. The best woollens, best cottons, the best pottery, the most expensive hardware of the British market, are *never* seen in this country, which is Britain's best customer. T. C.

The essential condition of a great division of labour, of the general use of machines, and of all the most valuable improvements of civilized society, is enlarged activity, and an extensive scale of operation.—There must be much travelling, and much conveyance of property, before we can think of stage coaches, turnpikes, and steam-boats. There must be a vast deal of conveyance of property, before there be question of canals, and rail roads. —*The aggregate industry of a country becomes productive o aggregate benefits, which are large, which are immense, precisely in proportion as the magnitude of the total exertions admits of the performance of every single operation in the larger way.*

Would the industry of the city, and county, of Philadelphia be what it is, if no intercourse existed beyond the county line? Would the state of Pennsylvania be what she is, if no commercial intercourse existed with the adjoining, and distant states? Would this trade, now so beneficial to her, be less so, other circumstances remaining the same, if the erection of separate governments in New England, in the Carolinas, or in Kentucky, transformed it, from a domestic, into a foreign trade? Or can it be imagined that a commercial intercourse with the island of Cuba, admitted to be beneficial if it could be called home trade, should cease to be so, merely because that island forms no part of our political union?*

But, if industry, from the reasons stated, becomes productive of wealth, in proportion as the different branches of it can be pursued *largely*, foreign trade must be productive of wealth, because it swells the number of consumers, which put every branch in motion, with additional millions, all over the world.

4. *Foreign trade is beneficial, because it is the surest means of preventing, both want† and waste.*

From the necessary effects of competition the prices of every species of produce of the growth of a country, which has no fo-

* It cannot only be imagined, but demonstrated. If the political union of the United States, were reversed, so that the commerce between Philadelphia and New-Orleans, which is now home trade, should become foreign trade, the value would be lessened by the change of laws, by political jealousies, political restrictions, and the chance of political hostilities induced by mercantile squabbles: none of which hazards exist at present. T. C.

† How far it prevents *want*, let the present state of England determine; one eighth of whose population are now paupers, *notwithstanding the war*, which has found employment for so many. The poor's rates of that country amount to six millions sterling, and the charitable contributions toward the support of the poor, to about one million more. T. C.

reign trade, will generally come down to their lowest rates—that is, to the rates at which those, who raise it are just compensated for their labour, and the investment of their capital. As soon as the price of any species of produce falls below this rate, less of it will be raised, till it has returned to the usual standard.

Since, therefore, consumption naturally limits production, it is obvious that *want* must take place whenever, from an untoward season, or any other cause, the usual crops fall considerably short. Consequently we see that all countries, which have little or no foreign trade, are occasionally subject to famine, with its attending train of disease, and horror. An exporting, agricultural country, is exempt from this calamity. Raising, generally, more than is wanted at home, there will, even in years of scarcity, still be enough for domestic consumption.* *Le superfiu*, as Say expresses it, *est le gage du necessaire !*†

An exporting manufacturing country has always extensive connections ready formed, and, with the means of purchasing, easily supplies itself from abroad on any extraordinary emergencies.

A country in which both, agriculture and manufactures, are limited by domestic consumption, must be necessarily within the reach of the calamities mentioned; and the more so, the less its territory is extensive, and the less are various its productions, and climate.‡

We have already seen that a country, deprived of foreign trade, cannot improve to the utmost the advantages *peculiar* to it. But, leaving any natural advantages unimproved, or improving them only partially, is a species of *waste*.

A further, and very injurious *waste*, in a country, relinquishing the benefits of foreign commerce, would result from the circumstances, that the refuse of many descriptions of manufacture, could be no longer turned to account; nor the injurious effects on industry, arising from the constant changes in taste, and fashion,

* Let us see how this consists with matter of fact. Great Britain is an importing and exporting agricultural nation. She gives a bounty on the export of grain. She has the most extended foreign trade the world has ever seen. France has none. Yet would Great Britain, 2 or 3 years ago been without bread to eat, had not her enemy France supplied her with grain to the amount of seven millions sterling. T. C.

† I. B. Say—Traite D'Economie politique.

‡ How does this apply to the United States of America? T. C.

and from the progress of improvement, be any longer successfully corrected.

The coarse woollen cloths of England, could not be afforded so cheap, nor made so good, as they are now made, but for the employment in that manufacture of the refuse wool of the superfine cloths. Circumscribe therefore the market for either, and both must become dearer, or worse.*

Tin shreds, and old iron hoops, would be of as little value in England, as they are here, if she did not supply with copperas nearly all the civilized world.†

The residues left in the processes, now employed for bleaching and other purposes, render many chemical preparations in England cheap, and exportable. Diminish the vent for these, and bleaching, and similar operations, will become more expensive.

The articles, out of fashion, or, turned by new improvements out of use, would become waste in England, and involve in ruin those who manufactured them, or bought them for sale, if the world were not before her, if an extensive foreign trade did not cause them to find a vent, in regions where different tastes prevail, or which are regularly somewhat behind hand in matters of fashion and civilization.‡ In consequence of this resource she is able always to consume herself, at moderate prices, what is newest, and what is best. Without it, all manufacturing operations must be carried on with much more timidity, and on a smaller scale, that is, with less profit. Improvements, and the spirit of exertion would be checked. The better article could not be brought forward, till the worse was sold off, or could only be offered at a price so high, as to compensate for the loss of the latter. The rewards of industry, and ingenuity, would become more precarious, and consumption itself would diminish, for want of the

* They are as much economized in our own country, where all refuse woollen can be worked up into home made carpets. T. C.

† I see no reason why we should not supply ourselves. It can be done to profit. T. C.

‡ I can well remember the outcries at Birmingham on account of the very convenient substitution of *covered* for metal buttons, of *strings* for shoe buckles, and buckles of the breeches knees. The Prince of Wales was petitioned to countenance buckles and buttons; and parliament I believe interfered against covered buttons. Surely this is not a benefit, but an evil resulting from the system of commercial manufacture. T. C.

stimulus to consumption, now found in the constant novelty, or the superior excellence, of the productions offered.

The utmost division of labour, therefore, unabated activity, unremitted exertions to extend improvements, enlarged ideas, and their great result—a steady progress of civilization—are only compatible with those prudential considerations that ultimately guide the conduct of individuals, in a country enjoying an extensive foreign trade. In such a one alone, that most useful description of citizens, the merchants, are able to take care that nothing, any where of value, be wasted, and that every natural or artificial advantage, be improved to the utmost.* The condition of most of those, which are deprived of this trade, is nearly stationary, all over the globe. Hungary—with her immense natural riches, the interior of Germany, Poland, Switzerland, Turkey, the beautiful regions of Africa, bordering on the Mediterranean, and China, are what they have been for centuries past,† whilst France, and particularly England, seem every thirty or forty years, to exhibit a new creation; whilst the United States, to judge from the rates of their progress since the revolution, bid fair to surpass, in time, even England herself. In both countries an extensive intercourse with the rest of the world has caused every commodity, and every production, that could be spared, or the use of which, at home, was superceded by a better commodity, and a better production, to find a good market abroad. *Nothing has been lost!* Gains have been multiplied by combined mercantile operations, between the most distant nations. Extensive information has become a productive capital. The rectitude of government, impartial administration of justice, and public credit—a source of wealth.‡ No individual riches have been hoarded, as they generally are in badly governed, or secluded countries, where thoughts and people become trifling and contracted. On the con-

* This is not the business of the merchant either in theory or in practice. It is the province of the manufacturer, whether for the home or the foreign trade. The merchant is a mere factor: he finds out markets, and purchases the goods there wanted. But he has nothing to do either with saving or improving as Dr. B. states. T. C.

† This is owing to political errors in Government—to ignorance among the people—to despotism—not to the want of trade. What trade has France had for these twenty years past? Yet has her power or her knowledge diminished? England has monopolized till a few years back, the trade of the world: has her power permanently encreased? Assuredly not, as I think. T. C.

‡ Are not these perfectly consistent with the home trade? T. C.

trary—the constant temptation to agreeable consumption, by an infinite choice of valuable commodities; and to new accumulation, by an extensive range for enterprize, have caused them widely to circulate, and to encourage industry in all its vast ramifications.

The preceding considerations appear to me to be the principal ones, that can be urged, theoretically, in support of the great utility of foreign commerce, and, I believe, they warrant the following conclusions.

1. Commerce generally is *more beneficial*, in proportion as it is *more foreign*—that is, the less resembling each other in their situation, habits, and local circumstances, the parties are between whom it takes place.

2. Foreign commerce, whenever it arises of its own accord, is useful as a matter of course.—It is exchange of commodities. None are delivered, except in return for others, and each party must prefer those it receives to those it gives. The business could not otherwise be pursued.

3. Foreign commerce is particularly useful to countries of which the territory—is small; the climate—little diversified; the productions and commodities of which are few in number, and peculiar in kind, whilst their situation facilitates distant intercourse.—The more an empire, like that of China, is a world in itself, the less the want of foreign commerce is to be regreted.*

I shall now proceed to examine the arguments which, in your political arithmetic you have advanced against foreign commerce, and against the *commercial system* generally—which must mean, the system of an unrestrained and extensive commercial intercourse between nations, and nations.†

But, in the first place, I should wish to object to the idea of

* This applies still more specially to the United States. T. C.

† I do not object to commerce, or the foreign trade. I am no advocate for restraining it. I think the interference of government to restrain or to promote, or in any way to guide and controul the effects of individuals to gain wealth, is worse than injudicious, unless under circumstances of state necessity; where the interference is, not to promote or protect the interest of the individual, but that of the nation.

But I think foreign trade is not so productive, so beneficial, so safe, so peaceful, as the home trade. I think it does not pay for national protection in any country. T. C.

any thing like system—agricultural, or commercial—in political economy, and even to the very term, applied in the manner in which it has been used.

With regard to individuals there may exist a system of agriculture, of commerce, &c.—that is a connected body of principles, and rules, according to which the cultivation of the soil, and mercantile pursuits are to be conducted. But, what we understand by agricultural, commercial, or manufacturing system, in political economy has no existence, except with regard to governments. According to the writers on that science we should imagine that every government has to determine whether to adopt the one, or the other—whether to protect agriculture, or manufactures, or commerce. Now this seems preposterous

1. Because no country can be, exclusively, agricultural, or manufacturing, or commercial. Even if a nation were settled on a rock, and subsisted solely by commerce, they must needs have among them a number of tradesmen, and artizans; a number of men—not merchants, equally entitled to the care of government, and to protection in their lawful pursuits; equally essential to the well-being of the community.—Governments would, generally, be wrong, in pretending to grant protection, or encouragement, to those addicted to certain pursuits more than to others.*

2. Because whatever doctrine theorists m ght attempt to establish, respecting the degrees of utility of the various main branches of industry—it could, obviously, not lead to any general rule, to any exclusive policy, by which governments ought to be guided, since the callings of different nations—if I may use the expression—like the callings of individuals, have been differently ordained by nature.

3. Because the sound, and only true policy, which ought universally to prevail, is to let individuals find out, what course of activity is, in the country to which they belong, the most beneficial, and afford security, and grant protection, in their lawful pursuits, indiscriminately to all.—"*laissez les faire.*"—As soon as government turns its attention to one of the systems it begins to err! Then why create them on paper, unless it be for the pleasure, too frequently sought by the learned, of displaying their perplexing sagacity!

* This is all I contend for. Let the merchant, the manufacturer, the farmer, each carry his goods to market at his own risk. T. C.

A more singular, and I might almost say, a more improper discussion, could hardly have arisen, than that concerning the respective usefulness of agriculture, manufactures, and commerce, in a national point of view.—We do not agree, whether it be better to be a joiner, or a black-smith ? a farmer, or a weaver ? and is it not the same with nations as with individuals ? All depends on their respective situation and faculties. Nor can it be imagined that one branch of industry should be incompatible with the other. The tradesman, who buys his grain, and his meat, does not on that account, preclude himself from cultivating a garden. The farmer, who has his linen made at home, does not therefore scruple to buy his cloth, and his hardware. Few pursue solely what they find it convenient, and useful, to pursue principally. We are called an agricultural, and commercial nation, yet, we have been, for some time past, in the habit of manufacturing a considerable proportion, perhaps nearly the half, of the several commodities we consume.

Whenever a considerable number devote themselves to one branch of industry in preference, as their main occupation, we may take it for granted that they have found it to be the most expeditious means of procuring an honourable subsistence ; and that they cannot be disturbed without injury to the state.

There should, therefore, in my opinion, be no question of systems. But, since they have been brought into discussion, let us see why you are so averse to that of foreign commerce. The enquiry will throw a further, and important light on the subject.

" *Capital*, you say, with Adam Smith, *employed in the home* " *trade, is more beneficial to the country than that employed in* " *the foreign trade, or the carrying trade.*"

The inference is—that therefore the home trade ought to be pursued, the foreign, and carrying trade relinquished.*

* The position is only *conditionally*, not absolutely *true*. If two adventurers from Philadelphia, the one to Lisbon, the other to Charleston, produce both *the same aggregate profits*, and put both *the same quantum of industry* in motion, no doubt the home adventure will be the most beneficial to the country, because the favourable, pecuniary and moral results, are *all our own*.

But, if the adventure to Lisbon were to put in motion as much industry at Philadelphia alone, as the adventure to Charleston puts

* I have never drawn such inference. T. C.

in motion at both ends of the voyage; and, if the profits, made by the Philadelphia merchant alone in the former, were equal to the joint profits of the Philadelphia and Charleston merchant in the latter—the position would *not be true.*—A superiority of profit or of industry put in motion, would even establish for the foreign voyage a decided claim to superior national utility.* The correctness of this observation is so obvious that it needs no proof.

Now it is well known, that the ndustry, put in motion by a voyage, other circumstances being equal, is nearly in proportion to the distance of the voyage.†—Our inland trade is carried on in boats, and waggons; our coasting trade, in small craft; the foreign trade, in vessels of a superior order, the building of one of which costs as much—that is, puts as much industry in motion, as perhaps the building of twelve, or fifteen, of the former.—But, not only the vessels are more expensive, their equipments also are more costly. Freights and insurance, consequently, amount to much heavier sums, and even the small charges will be much more numerous; so that a foreign adventure, which terminates well, often brings back a capital the double, or triple of the original cost of the outward cargo, whilst the gain of the shipper does not exceed the ordinary rate of mercantile profits.—In this respect we may say, that a barrel of flour, and every other commodity, *provided we transport it ourselves*, puts more industry in motion, in proportion as the market, we are able to find for it, is far removed.‡—If the merchant's gain is considerably greater at the same time, it follows that the country must benefit more by the foreign, than by the domestic expedition.

* That is *cæteris paribus:* all other circumstance being equal: as, that the trade to Lisbon requires no more expence of national protection, and puts in jeopardy the national tranquillity no more than the trade of Charlestown. T. C.

† I believe the direct contrary is the commonly-received, and well-founded opinion. The more distant the voyage, the less frequent the returns of capital; but the quantity of industry put in motion, does not depend upon the quantum of capital employed, but on the frequent return of it. A capital of 1000 dollars returned twice a year, puts in motion a quantity of industry equal to 2000 returned annually. T. C.

‡ I greatly doubt whether any merchant would act on this principle, and prefer a trade because it was distant. Besides, the expences of the crew are laid out abroad in great measure: and in fact it is universally true, that the more distant the voyage, the greater the risk, the less frequent the return of capital, the more is protection needed. It is also true, universally, that the industry put in motion by domestic trade is exclusively home industry; by foreign trade, foreign as well as home industry, T. C.

By these considerations, in combination with those detailed in the preceding pages, the truth of the *position* is materially weakened, if not entirely overthrown. But, were it unquestionably true, still the *inference* could not be admitted, without great limitation.

If foreign trade is less beneficial than the home trade, *and they were opposed to each other*, then, surely, the former ought to be relinquished. But, it so happens, that both are most vigorous, when pursued at the same time, and the deplorable history of the day proves but too well, that, with us in particular, the destruction of the one, is nearly tantamount to the destruction of the other.*

The same observation applies with regard to the carrying trade. The prosecution of one description of business does not necessarily presume another to be neglected. *The natural limits of the activity of a merchant are his gains.* You can confine him in no other without prejudice to the country.

——"*The capital*, you continue, *employed in the home trade*, "*circulates twice, or thrice, while a capital, employed in the foreign* "*trade, circulates but once.*"—

Inference—therefore the foreign trade, less profitable, is to be abandoned.

The position, again, is not generally true.—A capital between New Orleans and the Havanna, between New Orleans and Vera Cruz, may be turned twice, and oftener, before it can once be turned between New Orleans, and Pittsburg, or Lexington. The voyages from London to the ports of the German Ocean, are not longer than those from London to Liverpool, or the north of Scotland. Exchanges of property between Ostend and the British ports opposite, will be much more rapid than those between Ostend, and the French ports in the Mediterranean. A voyage from Archangel in Russia, to Odessa in Russia, would encompass the European continent—yet this would be home trade !†

Nor does the returns of the capital sent abroad—as the reader would be led to believe from your enumeration of the many hands through which it has to pass—depend on the realized proceeds of

* I am not aware that this position admits of satisfactory proof. T. C.

† These are merely local exceptions to a general proposition, the truth of which cannot be denied. But the point is, that home trade requires no national expence to protect it—induces no national risk—produces none but home feelings, home interests, home predilections. These characters do not belong to foreign trade. These are circumstances that operate universally, whether the trade be from Archangel to Odessa, from Boston to New-Orleans, from Dover to Calais, from Gibraltar to Ceuta. T. C.

the identical property shipped. Vessels, generally, bring back a return cargo promptly, and to the country it is immaterial, whether this be the actual proceeds of the outward cargo, or a property shipped in advance of the expected proceeds, or the results of some previous adventure. A regular intercourse once established, the returns depend no longer on sales, and mostly vessels bring back a value, equal, or superior, to that taken out. Consequently, in a national point of view, the capital employed in a foreign adventure, may be considered as replaced with a profit, as soon as the voyage is terminated. Were it otherwise, if the trade continue notwithstanding, it would only prove that the country has capital to spare, which it cannot employ, to equal advantage, in any different manner.

Further—if the *position* were strictly true, still the *inference* would not stand.

The question is not, whether the more profitable home trade, is to be abandoned for the less profitable foreign trade. There can be no such question, unless there were a deficiency of capital. If this deficiency existed, the capital would, of its own accord, seek, and find, the employment most profitable. But it is not likely to exist in a country like ours, that has commodities to exchange, and circulate by means of paper; because in such a country credit is capital, and credit keeps pace with the amount of exchangeable property.

The true question is this—if the home trade puts in motion industry, to the extent, for instance, of one million of dollars, and an additional foreign trade might put in motion industry, to the amount of half a million more—whether the nation is to forego this advantage, merely because the trade would be foreign,—and I believe you will agree that the strictest logic, even from your admitted positions, would hardly warrant such a conclusion.*

* I never drew any such conclusion. An opinion has long prevailed, that foreign commerce is the great source of national wealth: the English writers until about five or six years ago, were almost unanimously of that opinion. The British ministry, have for more than sixty years past even to the present day, held up in theory, and have practically pursued the same opinion. The modern politicians of this country, particularly those who are somewhat biassed in favour of British practices and theories, strongly support the same opinion. M. Say, M. Ganilh, Dr. Bollman, are decided advocates in its favour. I have done nothing but attempted to shew that this opinion is not well founded. That foreign commerce, is insignificant in point of amount to the produce of capital and industry employed at home. That it is a productive cause of modern war. That it induces national expences for its protection, far beyond

You next advert to "*the comparative importance of the foreign* "*trade, and home trade, in point of amount.*"—You endeavour to shew, that the amount of the latter trade, even in England, whose foreign trade is now the most extensive, dwindles into insignificance, when compared with the amount of the former, which confirms you in the opinion that the foreign trade ought to be relinquished.

In order to prove the relative inferiority, in England, of foreign to domestic trade, you have recourse to the custom house documents. You shew

"That previously to the year 1794 the amount of the exports "of Great Britain have never exceeded twenty five millions of "pounds sterling per annum,"—let it be granted!

And you state "that the merchants profits cannot be estimated "at more than 12½ per cent."—I do not object to it.

"Which, on the 25 millions exported from Great Britain, and "3½ millions, exported from Ireland, makes 12½ per cent on 28½ "millions, or, about 3½ millions sterling."—The calculation is correct!

From which you conclude "That the foreign trade of Great "Britain and Ireland, at one of the most prosperous periods of "British commerce, was not worth to the nation more than three "millions and a half of pounds sterling,"—a conclusion to which I can by no means agree.

You have, evidently, fallen into an error, so frequently committed by political writers, and which I have already noticed in another place—*the error of confounding the national gain, with the mercantile profits.*

They are so very different, that the national gains are often large, in proportion as the profits of the merchant are small. Nay *the nation often gains, and immensely too, while the merchant actually incurs loss.*

Suppose us at peace, trade open, flour at eight dollars per barrel, and an account arriving of a failure of crops in England, in consequence of incessant rains during the month of August. Flour rises to $12 per barrel—200,000 barrels are bought by our merchants, from our millers, at that price; they are exported in our own vessels. They cost, delivered in England, in consequence

its value. But *if it can* be profitably pursued without requiring national protection by means of a navy fit to enter into competition with the great naval powers of Europe, *then* it becomes worth pursuing. T. C.

of the accession to the first cost, of small charges, freight, and insurance, $ 15. They sell so as to neat only $ 14 per barrel. What is the result of this foreign trade?

The merchants lose one dollar per barrel, or $ 200,000.

But the nation gains

1. The difference between $ 8 and $ 12 per bll. is on 200,000 barrels—800,000
2. The expences thereon $ 600,000
   Less the merchant's loss 200,000

   400,000

Total neat national gain, $ 1,200,000*

To which, in fairness, we ought to add, all the good springing from the influx of so much additional stimulus to industry. Yet, according to your mode of estimating the results of mercantile operations, the nation would be, by $ 200,000 the poorer for having meddled with this foreign speculation.

The view of the subject, which I have just given, and the correctness of which will hardly be questioned, accounts for the phenomenon, that so often communities *thrive*, though merchants *fail*. The competition among these raises the prices of the native, or manufactured productions of a country, and though, in consequence of it, the more sanguine, and enterprising among them, will frequently ruin themselves, yet they will be seldom so egregiously mistaken in their calculations, that the country should not benefit by their labours. We also see, why banks, and similar institutions, which give facilities of trade to men of moderate means, contribute so much to the wealth of a country. In their absence much less business would be done. A few capitalists would keep the prices of domestic produce down, and maintain at high rates the prices of commodities imported from abroad. They would gain much in doing little; that is, they would cause the community at large to work for less, and amass colossal fortunes at the expence of the labouring classes.

Such is the case in South America, in Old Spain, in France.

* It is hazardous to prove too much. If I employ an outfit of 20,000 dollars, doubtless the tradesmen I employ will have their reasonable profit; all this profit is national gain; but if in the upshot of the transaction, I lose 1000 dollars instead of gaining 1000 dollars, is not the part of the national capital under my care diminished by that sum? can this be called a national gain?

T. C.

There, merchants seldom break, but squalid poverty is the lot of the people.*

Many more important deductions might be drawn, from the simple discrimination between *national gains*, and the *gains of the merchant*, but they would lead me too far. Let me apply it to the point under consideration.

Foreign trade is not carrying trade. If British merchants employed a capital of 28½ millions of pounds sterling, in effecting exchanges of property, in vessels not their own, between America, for instance, and the East Indies, and cleared by those operations twelve and an half per cent. on the amount invested—then perhaps the 3½ millions, resulting therefrom, would be all that the United Kingdom could claim as national gain. If British bottoms were used on the occasion, then the amount of national gain would swell by the sums earned in freight, and insurance, and by the benefits arising from the industry, put in motion in consequence of the construction and equipment of the vessels furnished. But, if the question is of foreign, not carrying trade; if the 28½ millions are employed in exporting British goods, in British bottoms, and in bringing back in return raw materials, and other commodities—then the national gains augment beyond calculation, and the merchant's profits sink into comparative insignificance.

In order to reason correctly, *we ought to give credit to foreign trade, for so much of the home trade, as it puts in motion!* Will you attempt to make the calculation? I confess that I should not like, myself, to undertake the task.† But I shall state the principal circumstances that ought to be taken into view.

How many vessels are employed in the foreign trade, and what is the number of artizans, and mechanics that derive their living from the construction and equipment of these vessels?

What numbers derive their support from providing this body of artizans, and mechanics, with food and fuel, covering apparel and lodging?

What proportion of the 28½ millions of property exported, consists of the value of raw materials, imported and paid for; or, of foreign commodities re-exported? For all the rest, being value

* I know no evidence of this in France. I do know, proofs of the most decided character, that this is the case in England. See Anal. Mag. Nov. 1813. T. C.

† The calculation seems to me to be easy enough. A thousand dollars spent at home, in a home-investment, puts in motion one thousand dollars worth of labour at home, and no more. Dr. Bollman's mode of reasoning would tend to prove that it put in motion a million's worth of labour. T. C.

made up by British labour, or British surplus, *is so much clear accession to national gain.* Those, whose labour is thus engaged, may be fairly considered as in foreign pay; and, since the people of England could not possibly consume themselves all their tin, all their copper, all their wool, &c. if you take away their exportation, there will be unquestionably so much diminution of the annual increase of national wealth.

What is the number of those concerned in the raising, or growth, of so much surplus produce exported, or the number of the workmen, whose consolidated labour contributes the principal value of the manufactured goods sent abroad?

What numbers, again, live by providing those with the necessaries and comforts of life?

How many articles are consumed in constructing, improving, and keeping in repair, the labour saving machines, which the foreign trade employs all over the kingdom?

How much industry is kept in motion on high roads, rail roads, canals, and rivers, by foreign intercourse? How much in the towns, by furnishing employment to agents, brokers, underwriters, carriers, and the tribe of clerks? How many husbandmen are at their ease, and exist in comfort, by feeding all these feeders on foreign commerce, together with their train, who give value to country produce by consuming it.

What similar effects are produced by the imports—to an equal amount—the returns from abroad for the commodities sent out?

The foreign trade, you say, requires the navy. Place before your mind's eye all the navy of Great Britain, ready for sea, and ask yourself—what talent, what labour, what industry was necessary to bring this prodigy into existence?* What amount of these would become useless, were it no longer wanted!

Beware of the mistake—if there was no navy those talents, that industry, would be better employed!—Of all our superfluities in food and apparel, of all our luxuries of every denomination, you might say as much. Yet cannot the savage, with his few wants, with his rags and jerked venison, people the wilderness, which disappears before civilized man.

* In my opinion, the man who would devise the means of surely, speedily, and permanently putting *out of existence*, every navy, of every power, in every part of the globe, would be the greatest benefactor to the human race, that mankind have yet known. Let half a dozen merchants in London excite a national clamour that their commerce is in danger, and the British navy carries devastation and death to every corner of the globe. T. C.

In political discussions in particular, we should never ask, 'what man *can*, but what he *will* do?' He will do much, when constantly stimulated, as he is in a great commercial nation, by new objects of desire, brought home from every quarter of the globe; when kept in unceasing wakefulness by an infinite and constantly changing combination, of interests and passions! Remove all this impulse, you see him, as in the interior of the island of Cuba, in the midst of an earthly paradise, surrounded by hundreds of acres, and by innumerable herds of cattle—his own—lying on a skin, and dreaming away a useless existence in apathy and sloth.

Much good, therefore, arises from foreign intercourse, merely as far as it stimulates, as far as it diffuses animation, and life, through the body politic; and perhaps, on allowing their proper weight to the different conditions I have pointed out, you will agree with me, that the benefits of foreign commerce cannot be correctly computed from the mere arithmetical results, exhibited by the balance sheets of the merchants.*

In further contrasting the immense importance of the home, with the insignificance—as you conceive it—of the foreign trade, you compute the amount of the former by estimating the gross, annual, agricultural produce of Great Britain at 150 millions sterling, and the produce of the labour of the manufacturers, and mechanics, for home consumption at 50 millions, which, with a proportionate allowance for Ireland, makes the whole amount of the home trade of the British empire, according to your idea, equal to 220 millions sterling.

But *trade*, agreeable to your own, and correct definition, is barter, is exchange of commodities between different persons.

When a man, therefore, cultivates a potatoe patch, and, after the potatoes have come to maturity, digs them out, and eats them up himself, he can hardly, on that account, pretend to be a trader, nor insist that the value of his potatoes should count in a general computation of the amount of domestic commerce.

Trade requires *circulation*, and when we mean to ascertain the amount of internal circulation, we have obviously to deduct, from the total amount of the proceeds of agricultural, and manufacturing labour, so much as does *not circulate*, that is, so much of the proceeds of their work, as the labourers consume themselves. But, as there are seven millions of cultivators in the British empire,

* No. Nor the evils. T. C.

who may be presumed to have good appetites,—and about five millions of manufacturers, and mechanics,* who probably like to keep themselves warm—these deductions will amount to a great sum.

Great Britain and Ireland, generally, export no grain, but they certainly export a considerable value in linens, and in woollen goods. We have, therefore, in order to find out what the home trade would be, *unaided by foreign trade*, for that is the real point under consideration—we have further to deduct from the value of the *circulating* agricultural produce, so much flax, and wool, as the foreign trade takes off *directly*, in the manufactured state.

We have further to deduct from the value of the same circulating agricultural, and manufacturing produce, so much as the foreign trade takes off *indirectly*, in consequence of the consumption of that vast mass of consumers, whom the foreign trade keeps consuming; for we have seen that so much of the home trade, as is thereby occasioned, is *indirectly foreign*. The foreign trade may justly claim it as its own.

But, if we deduct from the total value of the produce of agriculture, and manufactures,

1. So much as does *not circulate*. And from the portion which does circulate
2. So much as the foreign trade consumes *directly*. And further,
3. So much as it consumes *indirectly*—by which two items home trade would diminish if no foreign trade existed;

Then you will allow that the 220 millions of pounds sterling, which dazzle us in your political arithmetic, will shrink into a sum—*comparatively lean*.†

* The reverse of this, is about the true proportion. The late population returns state the number of families in Great Britain at 2,544,000: of which 895,000 only are employed in agriculture, 1,129,000 in manufactures, trade, and handicraft employments. The very poor, the rich and the professional, amount to 519,000. T. C.

† I see no reason whatever for these deductions. The home trade brings into market the value of consumable produce nearly as I have stated it: no matter how or by whom it is consumed. The value is not lessened whether the consumer be a foreigner or a native. The question is, what is the quantum of industry put in motion; this is measured by the consumable produce raised: it is of no consequence to whom it is disposed of, if its value be obtained. T. C.

The cause of foreign trade might also be pleaded, by leaving all, that I have said, unnoticed, and taking up the question, on the ground on which you have yourself placed it.

"Where is the great source," you ask, in speaking of Great Britain, "of the wealth of that powerful, and wealthy country? It "is in her spirited agriculture," you answer; "in 100 millions "sterling of farming capital, permanently laid out in buildings, in "fences, in roads, in canals, in machines. In 50 millions more, "annually expended in manures, in repairs, in exuberant cultiva- "tion. Here is the secret of 24 bushels of wheat per acre in Eng- "land, 16 in France, and 10 in this country."

But, according to your own statement the *bare mercantile* profits, arising from the foreign trade of Great Britain, and Ireland, amount to three millions and a half of pounds sterling per annum.

Consequently the bare mercantile profits of the foreign commerce of the British empire, with a simple accumulation of only five per cent. per annum, will produce, in the space of nineteen years, more than the whole, fixed, agricultural capital of England.*

In other words—if the mercantile profits, accruing to Great Britain and Ireland from their foreign trade, were every year put out at 5 per cent. interest—they would produce, in the short space of nineteen years, a sum more than sufficient to stock, with the means of wealth, and—of home trade if you please—such another country as England, in a manner equally ample as she is now stocked herself.

The bare mercantile profits, resulting from the foreign trade, re-produce, that is, double, the whole fixed agricultural capital of England in less than nineteen years.

Nay, before they become thus consolidated, and fixed, they will, *if their circulation is rapid*, be more than sufficient to cover the annual expenditure of 50 millions sterling for manures, repairs, and exuberant cultivation.

Thus, on the face of your own statement, *the secret of the secret, is the foreign trade.*

In the prosecution of your arguments against foreign com-

* And what is the agricultural capital doing all this time? Is it dosing during these 19 years? This mode of reasoning will prove any thing. But it is double edged. If the home capital be tenfold greater than the capital of the foreign trade, and this last will earn so large a sum in 19 years, the other will earn ten times that sum. T. C.

merce you further state "*that the lands of America stand parti-*
"*cularly in need of capital.*"—I believe they do; and therefore a foreign trade, diverting capital from agriculture, might, in our country, with some plausibility be objected to on that ground.

On the other hand,—a foreign trade, bringing foreign capital into the country, must be the more beneficial, for the same reason.

Which is the case? has not the foreign trade of America, for a long time, been carried on almost exclusively, with British funds? and was not a great proportion of it carried on, with British funds, down to the very moment of its late interruption?

The great influx of foreign capital, in consequence of foreign trade, and of the funding system, so frequently, and so improperly found fault with, is, unquestionably, one of the most powerful causes of the unexampled progress which agriculture, the arts, and manufactures, have made in this country during the short space of a century and a half—for it has not been longer settled. Foreign trade, and the funding system, are the very *hot beds*, in which they have so surprisingly thriven.

If there were no other arguments in favour of an unrestrained, commercial intercourse between nations, a view of the benefits derived from the influx of capital on the one side, and from the employment of capital, on the other, would alone be sufficient to establish firmly the doctrine of its superior usefulness.

Since capital consists, in the accumulated, and consolidated results of labour, during a lapse of ages of industry; it surely follows, that a young nation, secluding itself, and avoiding all intercourse with foreign nations, has to become *old*, before it can acquire a capital of its own, and enjoy the incalculable advantages it procures.* A young nation, on the contrary, communicating freely with nations of long standing, will participate largely of the advantages they derive from the labours of their ancestors.

To place this in a still stronger light—suppose a family, possessing absolutely nothing, should arrive and settle on a fruitful spot, and be left there to themselves. They will first have to *scratch* the ground, to raise the grain wherewith to satisfy their hunger, and, if possible, the surplus grain, wherewith to procure

* I cannot see this. Is the commerce between Philadelphia and New-Orleans, good for nothing, until they become foreign countries in respect of each other? Is it the worse, because it requires no navy at each place to be ready for mutual hostilities, whenever mercantile jealousy shall excite them? T. C.

a spade, and a cow. The spade, and cow must earn a plough and horse, and so on, in slow succession. Years will elapse before they can attain a tolerable degree of ease, exert their faculties to the best advantage, and make the most of their farm.

An untoward accident during this period may altogether destroy them. If, on the contrary, some rich neighbour, relying on their industry, on the fertility of their ground, had, for a due eventual consideration, supplied them at once, with all the stock, and implements, required for good farming, his capital would have placed them nearly in the same situation, as if they had been already at work for years; their exertions would have yielded greater results; their situation would have been infinitely less precarious, and they would have attained, comfort first, and, afterwards, independence and wealth, with much more rapidity.

If immediately after the termination of the revolutionary war, in this country, a non-intercourse with all foreign nations had been decreed, and enforced to this hour; if, previously to the revolution, as soon as the first settlements had taken place on this side of the Atlantic, all connexion with Europe had ceased—can it be imagined that our agriculture, that generally, our prosperity, would have by this time attained the height to which they have risen?*

Capital itself is a commodity, which, when uncontrouled, migrates from the country where it abounds, to that where it is wanted.

British capital, in the first instance, stocked our farms. British, and other foreign capital lined our shores with ships, and covered our rivers with small craft. Nine out of ten, of our manufacturing establishments, have been set on foot by foreign skill, and with foreign funds.

The profits of capitals lessen in proportion as their size augments. A young beginner, with small means, must work hard to live. Grown wealthy, the bare interest of his accumulations suffices for his wants, and he seeks ease. He therefore sets up another in business, and is content with a share of the profits. Thus both benefit. The former makes rapid strides towards acquiring a capital himself, and the latter derives from his means an income without labour.

* No. Foreign commerce is highly desirable on many accounts, while it can be pursued, peaceably. The question is, ought we in prudence to go to war for the sake of it? will it repay the cost? T. C.

It is just so between nations. The same benefits are realized by foreign intercourse, and foreign commerce, *without any previous concert.* They are the natural results of difference of situation and circumstances, and of the operation of the ever active, universally prevailing desire, to improve, in the best manner, the advantages possessed.

Thus your observation—that American lands want capital—considered with a view to ultimate effects, corroborates, instead of disproving, the great utility of foreign trade.—

"*Capital*, you pursue, *employed in the foreign trade, is more* "*exposed than capital employed in domestic trade.*"—True! but a trade, the profits of which do not cover the premium of insurance is not pursued.—We may insure, abroad or at home.

"*The merchant, and all the people employed directly by him,* "*rank among the unproductive classes of society.*"

It is time indeed the invidious distinction of productive, and unproductive classes should disappear from the pages of political economy.

There are no unproductive classes,* unless it be the class of gamblers; and even their activity might be proved to be less injurious than perfect idleness. But the proceeds of labour are not always *direct*, and *tangible.*

If you spend six weeks in reflection, and thinking, and afterwards two hours in explaining to an intelligent mechanic some new principle, which you have discovered, and the application of which enables him to accomplish his usual work, in half the usual

* By unproductive persons, are meant those whose labour is not employed to increase the mass of consumable product, such as food, cloathing, furniture, the comforts and conveniences of life, &c. It is evident that a farmer, a mechanic, an engineer, does this, directly or indirectly. How does M. Vestris or Madame Catalini do this? It seems to me a strange mingling of words and ideas, that should regard as equally productive, the farmer, whose time is spent in producing food, and the idle class of gentlemen, who have nothing to do but devour it: *fruges consumere nati.* This is like the reasoning of the British ministry, who reckon all their expenditures in wars abroad, naval or military—all the money they waste, as so many, not merely evidences of, but additions to the mass of national wealth. So that if half a dozen line of battle ships be sunk or destroyed, the nation is the gainer by all the industry which is put in motion by the sums expended to replace them. This may be good reasoning in England; but I cannot comprehend the force of it.

T. C.

time;—when you have finished, there remains no result of your labour that could be measured, or weighed. But, if the day following, and ever after, the industry of your hearer is equal to twofold the wonted task, who will say that your labour has been unproductive? you have doubled the usefulness of his existence.

What remains of the activity of congress, after they have risen? yet, a few sentences, passed into a law, and handed over to the chief magistrate, for execution, will animate, or paralyze the industry of unnumbered individuals, encourage honest pursuits, by security of reward, or drive whole classes at once as we see daily, by the magnitude of illicit gains, or the necessity of finding the means of subsistence; into the paths of smuggling, imposition, and fraud.

SAY, and after him the distinguished American commentator of the great MONTESQUIEU,* call merchants *manufacturers of peace.* The idea is somewhat quaint. It seems difficult, for us people of common sense, to conceive how space, unbounded, could be something fabricated, or even the occupancy of any defined section of it—peace—a production!—According to the same commenting luminary, the soil is only a *tool* in the hands of the husbandman, who manufactures wheat. By parity of reasoning, cows and bulls are the instruments of the breeder; and our graziers manufacture beef, by means of a judicious application of oxen to pasture!†

But—leaving such sublime conceits to those who, strangely enough, imagine that they soar with Montesquieu in kindred regions, or even presume to look down upon him with a sneer—I believe there is a species of commodity the importance of which has long been generally felt, and at which a plain intellect will not revolt, when it is brought into notice. I mean *convenience.*

* A commentary,

The shades of Monticello are particularly familiar to the author, who, with a candour, tout a fait unique! avows himself, in the preface, to be a Frenchman. Dr. B.

The commentary on Montesquieu, was written in French, by a Frenchman. It is too theoretical and too democratic for me in some parts; but I consider it as a work of considerable merit, and well worth perusing. T. C.

† I see nothing ridiculous in this view of the subject. It seems to me as substantially true, that a grazier manufactures beef, by applying the proper kind of food to his oxen, as that a cabinet-maker manufactures a chest of drawers, by applying the proper instruments to his log of mahogany. We might as well indeed keep to common language, which distinguishes them, but there is not much real distinction in the case. T. C.

Of this commodity, *convenience*, all traders and merchants, may truly claim the production, and its influence, on the general productiveness of labour, is incalculably great.

Without an exchange of the commodities produced, there could exist no division of labour. But, how many exchanges would take place, if the consumers were obliged themselves to *seek*, and *directly to traffic* with, the producers, or manufacturers? The enormous waste of time, which such a mode of supplying wants must occasion, would, inevitably, destroy all the advantages resulting from the division of labour—which would therefore *cease* —and render half the treasures of nature, and industry, useless, in consequence of their being placed, morally, beyond the reach of consumption.

The merchants, therefore, with their train, *create value, by creating convenience of consumption.* Without them, division of labour, if it existed at all, could not be carried to an equal extent. Without them, half the time of those whose labour is allowed to be productive, would be wasted in an unproductive manner. This obliges us to admit, that their activity, if not *directly* is at least *indirectly* productive. Their labours add nothing to the mass of matter, nor improve its form; but they cause, notwithstanding, more work to be performed, and the same amount of *directly productive* labour, to yield larger results, by being more advantageously applied.

If the industry of a million of people, without merchants, realizes the value of one million of dollars per annum, and, by turning one fifth of them into traders, and merchants, their industry yields, annually, the value of two millions of dollars, will any statesman say, that the labour of merchants is unproductive, and that they are to society a burthen rather than a benefit? Those who distribute tasks, and provide every department with the needful, are not the least needful in a large manufacturing concern. What interests society is the quantum of work performed, and if the greatest result were obtained, by causing a portion of the large family to be *idle*—the very *idleness* of these ought to be termed *productive.*

The same observations apply to those, whose offices are required for the maintenance of security, and for defence. I can see nothing unproductive in any of the situations, which an improved state of society, and great civilization, have brought forth. Cultivators, merchants, manufacturers, tradesmen; the officers of

government, judges and lawyers ; soldiers, clergymen,—physicians even—all are useful ;* all contribute, materially, to swell the great aggregate proceeds of general industry, provided their number do not exceed the due proportion.

No objection can therefore lie against foreign trade, because it requires merchants. On the contrary, the usefulness of this class of society—which, perhaps, has never yet been duly appreciated—is of the highest order.† The beneficial results of their labours—though only *indirectly productive*—are immense, and there is this peculiarity attending them, that often their contribution to the general wealth of society, and to its *beneficial distribution*, is great, in proportion as a sanguine disposition has caused them to provide but ill for their own.

"*Mercantile success*, you continue, *tempts to imprudent expenditure, and speculation.*"

I doubt the correctness of the observation, which, if true, would only be of minor importance. Mercantile success generally causes an increase of caution, and a greater desire to accumulate. Those who have acquired fortunes, mostly continue to enlarge them. Imprudent expenditure is more commonly the fault of wealthy landholders than of wealthy merchants. A speculation which ruins the speculator, not unfrequently enriches the country !

"*Merchants are of no country.*" Professionally they are not. Nor are they learned ! Will you therefore banish the learned ? Both may be patriots as men. A merchant at least, as such, always belongs to the country in which he resides. Where he trades, there his existence is beneficial. Of the learned, and even of many of our politicians, you cannot always say as much !

It is an erroneous idea, that merchants, by any effort of theirs, could set on foot, or cause to continue for any length of time, a foreign trade, injurious to the country.—Trade is exchange. There must be something that can be spared, before the reception of an equivalent is practicable. The equivalent received,

* No doubt : because all these classes are more or less necessary, directly or indirectly to the increase of consumable produce. But I cannot see how a Gamester, a Dancer, an Actor is so. They put industry into motion and give employment to many persons who might be more usefully employed. But their efforts add nothing to the stock of national wealth. Ipso usu consumuntur. T. C.

† I acknowledge that merchants and factors, are fairly to be considered in the same light as labour-saving machines. T. C.

must have a greater *relative value*, must be preferred, else the price would not be given. Nor will the importation of any commodity continue, as soon as the same commodity can be produced cheaper, or better at home. The merchant, in all his operations, is inevitably controuled by the nature of things. Should he attempt defiance—he will be ruined, and disappear.

"*Foreign commerce has never paid the interest of the sums spent in the prosecution of the expensive wars it has induced.*"

As you, and myself, value somewhat differently the benefits resulting from foreign commerce, we could also not well agree with regard to the amount of national expenditure for which they would compensate. If those benefits are so great, as I am inclined to think they are, the weight of your argument falls to the ground.

Independently of this, I cannot admit, that foreign commerce is the cause of all modern wars. This idea has seized on your imagination so forcibly, that it re-appears on almost every page of your political discussions—but is it true?* Or ought we not rather to say, that the passions of those who rule, have, in our modern times, found in the collisions caused by foreign commerce, the most convenient, and popular *pretext* for the wars which their gratification demanded!

I will not advert to our own situation at this moment. I will not say, that any rooted animosities, or inveterate prejudices of leading politicians; or the ever active, and unabating thirst for vengeance of a considerable body of foreigners, whom personal wrongs drove from their native shores, had the least share in bringing it about. I will not question that the western people, and particularly those of Kentucky, would be equally zealous in the defence of injured sailors rights, even if the war, in which we are engaged, should have drained their country of circulating medium, instead of making it abound; even if their produce should have

* I think it is. Look through the history of the European wars particularly those of England, and it will be found so. It is not a little singular that in 1738, the king, the lords, the commons, and the British people were actually outrageous in support of the principle that FREE SHIPS MAKE FREE GOODS. Sir Robert Walpole could not withstand the torrent; and one of the most efficient causes of his ultimate dismissal, was, that he did not take care to insert this principle as a national right, in his convention at PARDO; a right, in defence of which, the British nation actually went to war with Spain in 1739. Flags were displayed, and cockades worn in almost every town of the kingdom with mottoes such as FREE TRADE: NO SEARCH. *Tempora mutantur.* T. C.

sunk in value, in consequence of that event, as much as it has risen; even if the price of their saltpetre instead of an augmentation from 12½ cents per pound to 40 cents, should have experienced a proportionate depression. But let us look to Europe.

The recent pages of French diplomacy ring with splendid sentences in defence of neutral commerce. The philanthropic Napoleon steps forth the champion of injured maritime rights.* He, who knows no law but his will, is the great expounder of the law of nations; he, who respects no nation on terra firma, insists that the most insignificant should be respected at sea; and a *Tuscan*, his sword still reeking with the slaughter of pious fanatics, attempts to insult our government for not joining with sufficient alacrity in the common cause!

Is it the less true that *Napoleon* hates, and must hate, Great Britain; that he only seeks to destroy her supremacy on the ocean to be able to assume it himself?†

The commercial intercourse between nations, on an extensive scale, is of recent origin. Was antiquity less drenched in blood, because then such intercourse was unknown?—The Romans were not commercial—and they desolated the world. The Tartar tribes, with their herds, and their milk, subdued in their turn the Romans. The sword of the Turks spread devastation in Asia and Europe. Millions perished in the crusades. Religious feuds, subsequently, swallowed up a whole generation.—Yet, you would attribute the sufferings of nations in our times, to the sublime, though still imperfect policy, of linking all by ties of mutual usefulness!

"*The modern system of foreign commerce is the most produc-*
"*tive source of human misery.*"

We have enjoyed foreign commerce, and we have to bear our share of human misery—it is granted. But misery bore not less hard on the human race before our time.‡—You wish for the de-

* If Dr. Bollman will look at the state papers and manifestoes of the European powers at the time when Russia proposed the *armed neutrality*, he will find that FREE SHIPS, FREE GOODS, was then adopted as a principle of maritime law, by every maritime nation of Europe except Great Britain. I do not undertake the impossible task of defending Buonaparte, but he will not suffer by a comparison with his European contemporaries. T. C.

† An American ought to have no objection to these two powers worrying each other, till neither is able to usurp this hateful supremacy. T. C.

‡ Many of the antient sources of war, are done away. Is it absolutely needful that mercantile jealousy should furnish others to supply their place? T. C.

struction of all men of war. I, on the contrary, should hail him as the greatest benefactor of mankind, who should cause all national quarrels to be settled by seventy-fours.—If they were thus divided on the ocean, the labours of ages would become heaped on each other, and the accumulation of improvements and capital would be prodigious!

* Has not, in Europe, the introduction of the potatoe fattened millions, and called additional millions into existence? Has not the introduction of sugar changed the catalogue of diseases, and expunged one half from the former list?† Has not the introduction of cotton goods spread taste, and neatness, where before prevailed grossness, and filth?‡ Does modern civilized society know of any more universal and more inabuseable means of comfort, in health, or of solace, in pain, than coffee and tea? and are they not all the result of foreign commerce?§

You say, that colonization is the immediate offspring of foreign trade; and you will certainly grant, that these United States are the offspring of colonization!—well, I plead the cause of foreign commerce with these United States. They shall be my great argument.‖ I put into my scale of the question all this noble land, with its eight millions of people,—most miserable, and most wretched, as they are—all the population of the day, all the population of the times to come!—What have you to put into yours?

"*The most flourishing, populous, and best cultivated parts of Europe*, you say, *are not maritime, or commercial.*"

But, in endeavouring to elucidate this point, you confine yourself to numbers; and a mere superiority of numbers per square

* No. The consumption of potatoes as an *article of food*, is confined to Ireland. They are used here and in England, as a sauce, or condiment—an addition and auxiliary to the table. In 1792, in France they were almost unknown. Brissot and Claviere introduced them. T. C.

† Not that I know. T. C.

‡ Cotton goods, have introduced cleanliness and the consumption, Pthisis. T. C.

§ They may perhaps be somewhat pleasanter from being more fashionable than Balm, Sage, Chicory or Beet: I do not know that they are better in any respect. T. C.

‖ I cannot urge all that is to be urged on this subject. Those who desire to know the comparitive value of colonies to a mother country, must peruse Anderson and De Casaux. Ganilh talks absolute nonsense on the subject. T. C.

mile, does not establish the existence of a superior degree of individual prosperity, or of national wealth and power.*

There can be no doubt that, if in England you were to cut up, all the large estates into very small farms of ten, and fifteen acres each; if you were to turn all the pasture, and pleasure grounds, into wheat and potatoe fields, make men and women perform the labour of oxen and horses, and habituate the present hardy race to a meagre diet—you might succeed in adding one third, or perhaps, one half, to its present population. But England would then be no longer what she is! She would present, like China, or Flanders, a surface crowded with beings, scarcely human, all absorbed in barely prolonging a miserable existence.†— Instead of British cottagers, and farmers, you would have Egyptian fellahs,—an easy harvest for the sword of any invader! an useless load to the soil they encumber!

Here is one of the secrets of Bonaparte's successes.—There is no statesman, there is no philosopher, there is no philanthropist, who could not prefer, for their sake, and for his own, the 150 per square mile in England, or, even the still fewer per square mile in this country, to the 244 in Italy, or the 333 in China!‡

"*The commercial nations have uniformly fallen before the agricultural nations.*"

But no nation ought to be, or can be, exclusively commercial. But, in complicated questions, all vague appeals to history are extremely apt to lead to false conclusions. But we know so little of the people of Tyre, and of Sidon. But Tyre, and Sidon, and Carthage, which you adduce in proof, existed as nations previously

* It does under a good government: according to the principles laid down by Dr. Bollman in the beginning of this essay; to which I give my full assent. "That system of political economy is the best, which affords comfortable subsistence to the greatest number of persons upon the smallest "territory; provided the system be permanent in its principles." If then we see a country very full of inhabitants, living in reasonable plenty and comfort, we have a right to conclude accordingly. T. C.

† England is in fact at the present moment, and has for many years been, *crowded* with beings who drag out a miserable existence. It is true that lately the war has thinned them, and created something nearer to a sufficiency to support life for the rest: but where else is the country, where one eighth of the population are paupers? Soon after the peace of Amiens, in 1803, the poor's rates of England, amounted to 5,318,000 pounds: the returns were again to be made this year, 1813: but I have yet seen no acount of them.

T. C.

‡ I regard China as greatly exaggerated. T. C.

to the Romans;—the struggle between the two latter remained long undecided, and was at last decided by superiority of tactics, and military genius, more perhaps than by their superior estimation of agricultural pursuits. But the agricultural Romans were themselves overcome by the Huns, and Vandals,*—must we therefore take our lessons of political economy from these?

Permit me to conclude my remarks in vindication of foreign commerce, by adding one more argument to those adduced already, the force of which, it appears to me, cannot be easily resisted.

The wealth of a nation, as you have stated, consists in the aggregate wealth of the individuals of which it is composed.

Nine tenths of the population of almost every country are engaged in agriculture, and manufacturing pursuits.

The wealth of a nation, therefore, *depends chiefly* on the prosperous condition of these.—The lazaroni of Naples, the fellahs of Egypt, the zaragottas of Mexico, the canaille of any country, add nothing to the wealth, or power, of the political families to whom they belong.

But the condition of these, engaged in agricultural, and manufacturing pursuits, cannot be prosperous, unless the rewards of their labour somewhat exceed the measure, indispensible for the bare support of animal life.

Now in any fully peopled country, the price of any species of produce, or commodity, within the reach of general competition, can only be maintained above the rate, which the bare support of animal life requires, by means of foreign commerce.

The reason cannot be mistaken.—Domestic consumption is limited, whilst only want of food can limit population. Therefore competition, or, in other words, the struggle for existence, will always bring the supply of the great mass of domestic commodities full up to the demand, and prices must consequently sink down to the lowest rates.†

* The Huns and Vandals had no foreign trade. T. C.

† True: in a country overpopulated, and badly governed. It is so in England, where the preference in foreign markets is chiefly owing to the low price of the commodities: a low price, dependant on the intolerable labour, and hard living of a starving manufacturing populace. The profits of the capitalist—the commerce of the nation is supported out of the life-blood of the labouring peasant and manufacturer. T. C.

Foreign consumption, on the contrary, has no limits, and the merchants—the agents between domestic producers, and foreign consumers, are constantly on the watch to extend its sphere.

Therefore foreign commerce is the surest, and perhaps the only means, of maintaining the staple commodities of a nation, at prices which will insure to the mass of the people the enjoyment of substantial comforts, and allow them to be rational beings, and men, instead of mere drudges, and beasts of burthen.

LAUDERDALE has well described the surprising effects of a little deficiency, or excess, in the supply of a commodity, on its market-value.* A trifling quantity less in the market, than the demand would require, often doubles the price of the whole stock on hand.—A trifling excess, as rapidly brings it down. But, when the holders are not in distressed circumstances, the *rise* from a demand, in the smallest degree larger than common, is much more certain, quick, and considerable, than *depression* from the opposite cause.

When I shewed before, how the supposed information of a deficiency of crops in England, and the consequent exportation of 200,000 blls. of flour, caused the country to gain 1,200,000 dollars, though the merchants lost money by their speculation, I did not pursue the consequences further; because my only object was, to shew immediate, numerical accession to the national wealth, in consequence of the foreign, commercial operation, to which that information had led. It is obvious, however, that, on account of the general advance of the price of flour, caused, in the supposed case, by the foreign demand, *the domestic consumers of that article also, had to pay* $12 *instead of* $8.

If this domestic consumption throughout the Atlantic states, amounted, during the elevation of the price, in consequence of foreign demand, to 500,000 barrels, then the foreign demand; though, in its direct effects, worth to the nation only $1,200,000, would be worth, to the agricultural interest, two millions of dollars besides.—The home trade, according to your mode of estimating it, would be indebted to the foreign trade, for an immediate, additional importance to the amount of the stated sum. But, what is of infinitely more consequence, the millers, and farmers, would receive an additional compensation of two millions of dollars for their labour, *through the home trade, as operated upon by the foreign trade;* this shews, that the foreign trade prevents the consumers

* An inquiry into the nature and origin of public wealth.

from making the law to the producers, with regard to price;—that it is one of the most powerful means *of a general distribution of wealth;* and that, in consequence of this distribution, wealth becomes more productive of wealth; becomes more productive of national power; becomes, in every point of view, more beneficial to the state.

Such are the *great home effects*, of even a *little exportation.* I am well aware that a surplus in the market, in consequence of a want of the usual demand for an article from abroad, must operate the contrary way.—But, this evil is casual, whilst a depressed value of the great articles of consumption—which becomes *stationary*—and the poverty of the great mass of the people, thence ensuing, *are certain*, and *regular results of a want of foreign trade.*

Moreover—in this state of things the people naturally remain without relief, whilst in the former, the ingenuity, and enterprise of the merchants, prompted by self-interest, are unremittingly, exerted to provide a remedy.—The calamities to which a nation is subject from the want of foreign trade, can only be removed by the greater calamities of famine, pestilence, and war. The resources against these, to which, even with a foreign trade, they remain occasionally subject, are found in mercantile skill, and are commensurate with the extent of the globe.

Extract from Quart. Review for December 1812. *Inquiry into the poor laws, &c.*

I do not cite this book from any deference I pay to the opinions of the persons who write for it, or from any admiration of the ability or knowledge with which it is conducted, it is far from deficient in classical literature, but it does not and cannot maintain its ground against the Edinburgh Review, which is certainly conducted with much occasional talent. From the circumstance of the writers being anonymous, both reviews assume a stile of ungentlemanly insolence, that would not appear, if the names of the writers appeared also. But with far inferior merit, the tone of vulgar abuse, which the Quarterly Review indulges in, and the canting affectation of orthodoxy that characterises it, are extremely offensive.

I quote the following passage, as an advocate in court would press into his service adversary evidence.—

The system of Great Britain, is a system of manufacture founded on foreign commerce; and it is to this system that the following remarks apply, and they apply very forcibly. I do not choose to copy the abuse which this writer heaps on Malthus, Adam Smith, &c. for my object is to instruct, not disgust my readers.

But during the last forty years, a tremendous change has been going on; it has affected all classes, few for the better, the lowest and most numerous much for the worse.

One chief cause of this great moral revolution, for such it may truly be called, is to be found in the improvement of machinery, and the consequent rapid increase of manufactures. The manufacturing system has been carried among us to an extent unheard of in any former age or country; it has enabled us to raise a revenue which twenty years ago we ourselves should have thought it impossible to support, and it has added even more to the activity of the country than to its ostensible wealth; but in a far greater degree perhaps, has it diminished its happiness and lessened its security.****

Some of the sciences and many of the arts require large cities to foster them; they thrive there like exotics in a town-conservatory; but the virtues and the comforts of inferior life wither away in such atmospheres, like flowers transplanted from the field to pine at a street-window. The peasant, however much his religious education may be neglected, cannot grow up without receiving some of the natural and softening impressions of religion. Sunday is to him a day of rest, not of dissipation: the sabbath bells come to his ear with a sweet and tranquillizing sound; and though he may be inattentive to the services of the church, and uninstructed in its tenets, still the church and the church-yard are to him sacred things: there is the font in which he was baptized, the altar at which his parents became man and wife, the place where they and their fathers before them have listened to the word of God, the graves wherein they have been laid to rest in the Lord, and where he is one day to be laid beside them. Alas for him, who cannot comprehend how these things act upon the human heart! The town manufacturer is removed from all these gentle and genial influences; he has no love for his birth-place, or his dwelling-place, and cares nothing for the soil in which he strikes no root. One source of patriotism is thus destroyed; for in the multitude, patriotism grows out of local attachments. *Omne solum forti patria* may be said by the exile and the cosmopolite philosopher, but *natale solum* is found among the periphrases for *patria*, and the same feeling will be found in the language of every people who are advanced one degree beyond the savage state.

The manufacturing poor are also removed from other causes which are instrumental to good conduct in the agricultural classes. They have necessarily less of that attachment to their employers which arises from long connection, and the remembrance of kind offices received, and faithful services performed,—an inheritance transmitted from parent to son: and being gathered together in herds from distant parts, they have no family character to support in the place to which they have been transplanted. Their employments, too, unlike those of the handicraft and the agriculturist, are usually so conducted as to be equally pernicious to mind and body. The consumption of life in some manufactories, even in those which might at first be thought most innocuous, though it may be a consolation to those philosophers who are afraid of being crowded at the table of nature, would make good men shudder if the account could be fully laid before them.

John Hunter predicted that our manufactories would engender new varieties of pestilence. New and specific diseases they have

produced, but the only pestilence which has yet manifested itself is of a moral nature. Physical diseases are not more surely generated by crowding human beings together in a state of filth and wretchedness, than moral ones by herding them together in a state of ignorance. This is the case under the least unfavourable circumstances which can be imagined; but it is doubly so under the manufacturing system, where children are trained up in the way wherein that system destines them to go, as soon as their little fingers can twirl a thread, or feed a machine. When that system was at its height, the slave-trade itself was scarcely more systematically remorseless. The London work-houses supplied children by waggon loads to those manufactories which would take them off the hands of the parish; a new sort of trade was invented, a set of child-jobbers travelled the country, procuring children from parents whose poverty was such as to consent to the sacrifice, and undertaking to feed, clothe and lodge them for the profits of their labour. In this manner were many of our great manufactories supplied! The machinery never stood still. One set of these poor children worked by day, another by night, and when one relay was relieved, they turned into the beds which had been vacated by the other, warm as the others had left them!—When this system had continued long enough for those who lived through so unnatural a childhood to reach the age of maturity, it was found that the girls, when they married, were utterly unable to perform the commonest and most indispensable domestic work: and the remedy which was devised, in future, was that they should go to school to learn these things for an hour in the day, after they had done work!

These evils have been mitigated: the hellish practice of night-work (it deserves no gentler qualification) is nearly, if not totally disused; but enough which is evil remains to produce irreparable injury to the individuals and the most serious mischief to the community. The existing race of the manufacturing poor have been trained up certainly without moral, and it may be said, without religious instruction also; for if a pulpit lesson should now and then by accident reach their ears, there is little chance of its penetrating farther, utterly unprepared as they are to receive it. Among the philosophers-errant who mislead themselves as well as others in confounding the distinctions between right and wrong, there are some who, after wandering about the debatable ground between good and evil, recover the right path, and find grace to thank Providence for their escape. The bias inclines that way in the middle and higher ranks; for morals, as well as manners, follow the mode, and decorum, at least, is in fashion. But the class of which we have been speaking, have more to resist, at the same time that they are less prepared for resistance. He who has ever seen the habitations of the city-poor in the cellars and garrets of courts and alleys, will easily believe that the fire side of the pot-house holds out a stronger temptation than even the physical effect of the liquor. Goldsmith has told us how such places

'impart
An hour's importance to the poor man's heart;'

But they do more than this: they afford a stimulus of society which he cannot find elsewhere; strong humour and vulgar wit come

with double fascination to those whose intellectual powers are stagnant at home; the coarseness of boisterous mirth acts upon them with double excitement; and if they give themselves up to the lowest vices, ought we to wonder at this, when their better faculties have never been brought into action? Scarce lower than the angels in the capacity of his nature, man is yet, when left to himself, scarcely above the brutes; and if he be depraved, as well as ignorant, he is then chiefly distinguished from them by the fatal prerogative of possessing a wicked will and greater powers of mischief. When his diviner part has never been called forth, the mere animal is all that remains, and mere animal gratification must be the natural end and aim of his blind desires.

These are not the mere imaginations of a speculative moralist. It is notorious that the manners of the people in manufacturing districts are peculiarly dissolute. Saint Monday is the only saint in the journeyman's calendar; and there are many places where one of the working-days of the week is regularly set apart for drunkenness, like a sabbath of irreligion. However high the wages may be, profligacy of every kind keeps pace and draws after it its inevitable punishment of debility, disease, poverty, want, and early death. For the main cause of the increase of pauperism it is needless to go farther than the increase of manufactures,—that very increase which has so often been triumphantly appealed to in proof of the prosperity of the country. Even in quiet times, and when to all outward appearances, the country was flourishing beyond all example in former ages, the evil was felt, an evil in itself of sufficient magnitude, but of the most frightful nature when those circumstances are considered which give it a direct political bearing. This tendency was noticed some years ago in Espriella's Letters, a book in which, amid lighter matter, grave subjects are sometimes touched with a deeper spirit of thought than appears upon the surface.

'Two causes,' says the author of that book, 'and only two will rouse a peasantry to rebellion; intolerable oppression, or religious zeal either for the right faith or the wrong: no other motive is powerful enough. A manufacturing poor is more easily instigated to revolt. They have no local attachments; the persons to whom they look up for support they regard more with envy than respect, as men who grow rich by their labour; they know enough of what is passing in the political world to think themselves politicians; they feel the whole burthen of taxation, which is not the case with the peasant, because he raises a great part of his own food; they are aware of their own numbers; and the moral feelings which in the peasant are only blunted are in these men debauched. A manufacturing populace is always ripe for rioting: the direction which this fury may take is accidental. In 1780 it ran against the Catholics; in 1790 against the dissenters. Governments who found their prosperity upon manufactures sleep upon gunpowder.

'Do I then think,' continues the writer, 'that England is in danger of revolution? If the manufacturing system continues to be extended, increasing as it necessarily does increase, the number, the misery, and the depravity of the poor, I believe that revo-

lution inevitably must come, and in its most fearful shape. That system, if it continues to increase, will more effectually tend to ruin England than all the might and all the machinations of her enemies were they ten times more formidable than they are. It communicates just knowledge enough to the populace to make them dangerous, and it poisons their morals. The temper of the mob has been manifested at the death of Despard, and there is no reason to suppose that it is not the same in all other great towns as in London. It will be well for England when her cities shall decrease, and her villages multiply and grow; when there shall be fewer streets and more cottages. The tendency of the present system is to convert the peasantry into poor; her policy should be to reverse this, and to convert the poor into peasantry; to increase them and to enlighten them; for their numbers are the strength, and their knowledge is the security of states.' * * * * * *

Among the circumstances that favour the disorganization of the lower orders, the manufacturing system again presents itself in the first rank. *The extent to which it has been carried, makes a large part of our population dependent for employ, which is, in fact, for subsistence, upon other countries; and when the tyranny of a frantic barbarian in Europe, and the servility or corruption of a ruling faction in America, shuts us out from our accustomed market, distress and riots in the manufacturing districts are the consequence.* Let it not be supposed that we are among the wholesale declaimers against foreign commerce; or that, because we perceive the fatal consequences which result from the manufacturing system, carried on as it has hitherto been, we would, in the spirit of radical reform, destroy it root and branch. Doubtless it has been productive of great and essential benefit. But as nations may be too warlike for their own happiness, or even their own security, so they may be too commercial. * * * * * *

In other times we have had men thrown out of employ by the fluctuations of foreign politics, but their numbers have been comparatively trifling, and the effect partial; nor were there in those days public speakers and public writers ready to inflame their discontents and array them against their rulers. The rapid increase of manufactures, and the wider scale upon which hostility is carried on against us, have caused the effect now to be felt over every part of the country; and a cause which arises out of our real improvement and the high civilization to which we have attained, has given consistency to the danger. * * * * * *

The first duty of government is to stop the contagion; the next, as far as possible, to remove the causes which have pre-disposed so large a part of the populace for receiving it. We shall do little if we do not guard against a recurrence of the danger by wise and extensive measures of prospective policy. The anarchists may be silenced, and the associations of their disciples broken up; but while the poor continue what they are, continuing also, as they must, to gain in number upon the more prosperous classes, the materials for explosion will always be under our feet.

The first and most urgent business is to provide relief for those upon whom the pressure of the times bears hardest. Charity is no where so abundantly and munificently displayed as in England, not even in those countries where alms-giving is considered as a com-

mutation for sin; but mere charity is not what is needed in this emergency. The various plans which have been devised, and the local and partial experiments which have been made for bettering the condition of the poor, as reported by the society embodied for that purpose, are highly honourable to the members of that society, and to the land in which they exist. The society which has been formed under the auspices of the Duke of York, for the immediate purpose of affording assistance to the distressed counties, is doing much; and there is cause to hope that the benefit which must result from its encouragement of the fisheries will continue after the emergency is past. The food which is thus brought into the market is so much clear gain; it is nutricious; it is the cheapest which can possibly be procured; it is drawn from a source of supply which is inexhaustible, and the mode of procuring it adds to our best defence, by keeping up a nursery for our fleets.

There is another way by which employment might be provided for many of those whom want of work renders not only burthensome, but dangerous to society, and from which permanent good would ensue to the community. These ends might be attained, if our great landholders could be persuaded, instead of adding estate to estate, till they count whole districts, and almost whole counties within their domains, to apply the capital, that is thus directed, to the better purpose of doubling the value of the lands which they already possess, by bringing them into the highest state of cultivation of which they are capable. How many are the marshes which might thus be drained, the moors which might be reclaimed, the wild and lonely heaths which would be rendered productive, and where villages would grow round the first rude huts of the labourers! Great indeed is the present relief which might thus be afforded to those who need it, the permanent advantage to the country, and ultimately to the principal landholders themselves: but that they should thus see their true interest, and act upon it, is rather to be wished than expected. Of all the maxims of proverbial wisdom which experience has bequeathed to mankind, there is none which is so seldom practically applied, and few which are so widely applicable, as that which is contained in the old Ascræan's exclamation,

Fools do not know, that the half may be more than the whole.

It may seem, perhaps, paradoxical at first to assert that a season of pressure like the present, is a fit season for undertaking national works; yet nothing can be more certain, than that the public must in some form or other, support those who are deprived of their usual employments; and that it is better to administer this relief in the form of wages, than of poor-rates. The mouths cannot be idle, and as the great object is to prevent the hands from being so, a time when there are many hands out of employ is, of all others, the time for such labours. One way or other, be it remembered, the men must be maintained: it is therefore more wholesome for the community to have the advantage of their labour, and for themselves to feel that they earn their own maintenance, than that they should be fed gratuitously, and that we should have a race in England half Luddite, half Lazzaroni. No time, therefore, can be so proper for national works, for making new naval stations and improving the old, for cutting roads, draining fens, and recovering

tracts of country by embankments from the sea. Better is it to engage in works of ostentatious convenience,—better would it be for the state to build pyramids in honour of our Nelsons and Wellingtons, than that men who have hands, and are willing to work, should hunger for want of employment.

Things of this kind (and many such might be devised) are palliatives, which in this case are all that are required; this part of the evil being but for a season. The radical evil can only be cured by a course of alteratives. * * * * * *

Reverting to immediate relief, as well as permanent good, why should not government extend its military and naval seminaries, so that every body who needed an asylum should know where to find one? Would it not be better that the workhouses should empty themselves into our fleets and armies, than that they should pack off children by waggon-loads, to grow up in the stench and moral contagion of cotton mills while the trade flourishes, and to be thrown out of employ, and turned upon the public when it meets with any sudden revulsion? Seminaries of this kind may be so conducted as to cost little more than well regulated workhouses. Boys become useful at sea at a very early age. There is no danger of overstocking ourselves with seamen; in peace the merchant service will require all that the navy can dismiss, and in war we know what is suffered from the difficulty of procuring hands. Train up children for the land and sea service, instruct them too in their moral and religious duties, encourage them by honorary rewards, pension them off after they have served as many years as their country ought to require: they will love the service; and the arts of our enemies will be as unavailing as their arms. For the surplus of an army, when war shall be at an end, there is indeed no such immediate employment as would be offered for our seamen; but the same means which would, above all others, tend to promote the power and security of Great Britain, would provide an outlet for this redundance also.

The subject of foreign trade puts me in mind of the following strange Jeu d'esprit *of the late Professor* Porson.

THE DEVIL'S WALK.

From his brimstone bed at the break of day,
A walking the Devil has gone;
To visit his snug little farm of the earth,
And see how his stock goes on.

And over the hill, and over the dale,
And he rambled over the plain;
And backward and forward he switcht his long tail,
As a gentleman switches his cane.

And I pry'thee friend, how was the Devil drest?
Oh! he was in his Sunday's best:
His coat was red, his breeches were blue,
With a hole behind which his tail went through.

He saw a lawyer killing a viper
On a dunghill near his own stable;
And the Devil was tickled, for it put him in mind
Of *Cain* and his brother *Abel*.

He saw an apothecary on a white horse
Ride by, on his vocation;
And the Devil was pleased, for he thought he beheld
His friend DEATH in the Revelation.

He saw a cottage with a double coach house,
A cottage of gentility:
And the Devil he smil'd, for his darling vice
Is pride which apes humility.

He went into a rich bookseller's shop;
Says he "we're both of one college;
"For I myself sat, like a cormorant once
"Hard by the tree of knowledge."

As he pass'd through Cold-bath fields, he saw
A solitary cell:
And the Devil he paus'd, for it gave him a hint
For improving the prisons of hell.

Down a river did glide with wind and tide
A pig with vast celerity;
And the Devil he grinn'd, for he saw all the while
How it cut its own throat, and he thought with a smile
On England's commercial prosperity!

He saw general Gascoigne's burning face,
Which fill'd him with consternation;
And back to hell his way he did make,
For the Devil he thought (by a slight mistake)
'Twas the *general conflagration!*

PORSON had imbibed the common, indiscriminate, and therefore silly prejudice, entertained in England against law and lawyers. Luckily for that country, he had no opportunity of witnessing what great things might be done, by making every man his own lawyer, every tavern a court of justice, and investing every citizen of the state, with the qualifications of a lord Mansfield by an act of the legislature. Porson knew nothing of arbitration laws, arbitration courts, arbitration decisions, and arbitration costs; nor of the convenience of bringing justice home to every man's door; that is to the nearest tipling house. He did not know with what peculiar felicity, the lawyers of this country are denominated gentlemen of the *bar!*

He had seen something of the presumptuous and daring despotism of a party in power, in England—but he had not witnessed the republican improvements introduced by the legislative judges here, on the paramount and convenient principle of DISPATCH. Those who have witnessed such things, will excuse many of the evils attendant on the legal system of their own country; and view with patience at least, if not with respect, the calumniated forms of legal proceedings, which expedience and experience must have had so large a share in establishing. All good has its attendant evil; and doubtless, time will point out gradually, the best remedies for such evils as are remediable. But ignorance, is a presumptuous, impatient, headlong reformer. Ignorance sees no difficulties; takes no pains to amalgamate the future with the past; or to join with the dexterity of a master-hand, the new to the old. Reformation, ought to bear upon his front, the motto, *Festina lente.*

NOTICE.

I have said, that six owners of furnaces in Manchester, were fined 100 pounds sterling each for not consuming the smoke of their fires, in the year 1796: the year is a mistake; but the fact is so; and there is a short report of the case in the Monthly Magazine, Vol. XII. page 76. It happened in August 1801, and instead of six, eleven were so fined.